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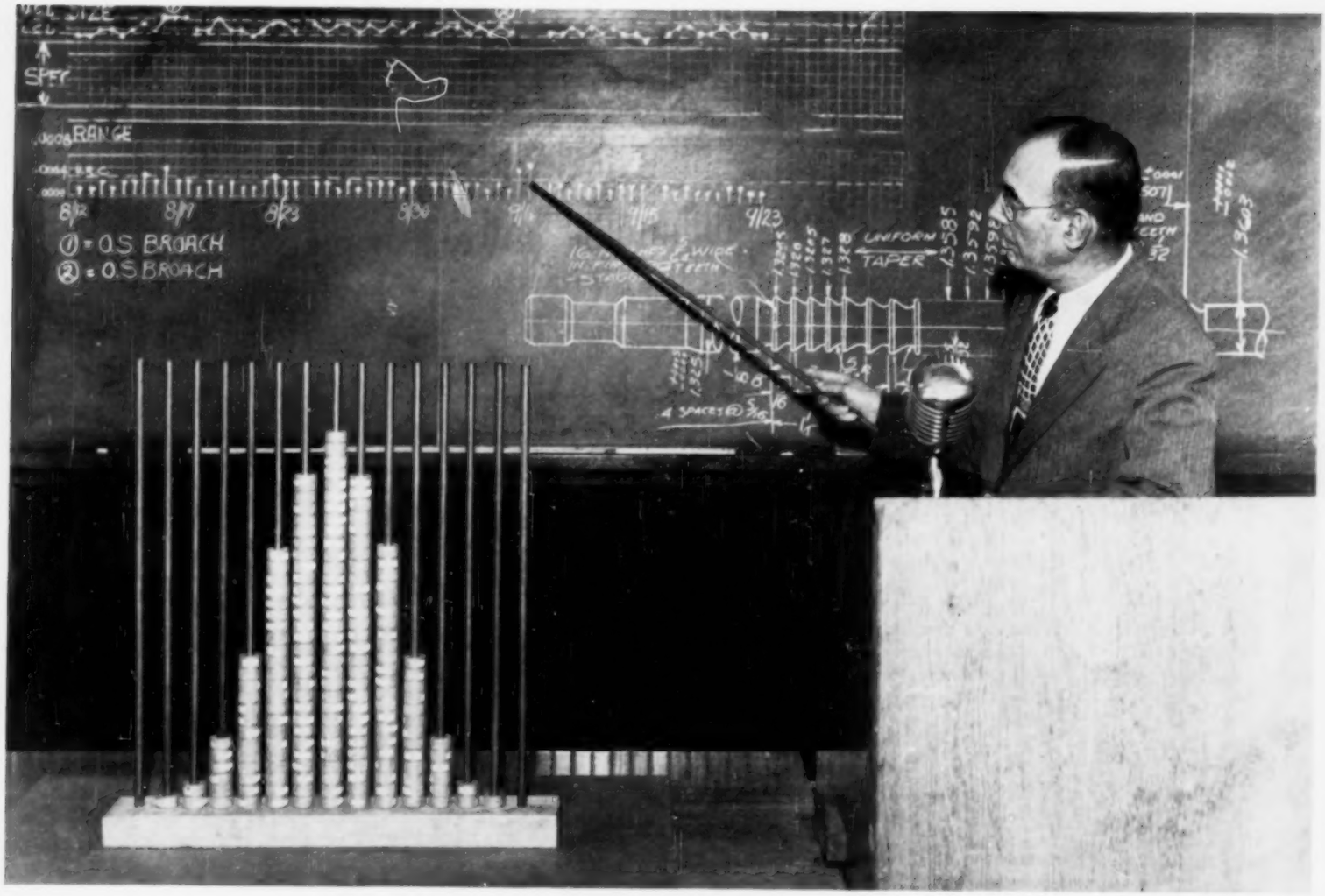

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March 6, 1947:
"What Controls a Quality Control Program," C. West Churchman, University of Pennsylvania.
April 3, 1947:
"The Use of Correlation in Research and Production", Peter Di Paola, Long Beach, New York.

Newark Section
February 28, 1947:
Metropolitan New York Meeting, Engineering Building in New York City. Dr. Mottley, Bureau of Ships, speaker on metallurgy.

Northeastern Indiana Section
February 12, 1947:
"Machine Variability", George Glenn, General Electric
March 12, 1947:
"$\overline{X}$ and R Charts and Its Application to Particular Problems", C. W. Kennedy, Federal Products Corporation.
April 9, 1947:
"Use of Charts and Diagrams; Establishment of Control Limits Without Calculations", A. E. Bender, Delco-Remy Corporation.

Ohio Section
February 14, 1947:
"Quality Control Proves Itself in Assembly", Martin A. Brumbaugh, Bristol Laboratories, Syracuse, New York, at Cleveland Engineering Society in Cleveland.

Philadelphia at Temple University
February 21, 1947:
"The Difference Control Chart with an Example of its Use", Lt.-Col. Frank E. Grubbs, Aberdeen Proving Ground.
March 21, 1947:
"Acceptance Sampling in Quality Control", G. R. Gause, Bell Telephone Laboratories.
April 11, 1947:
"Building and Maintaining Quality Consciousness", C. R. Scott, Jr., SKF Industries, Inc.

Hartford Society
February 19, 1947:
"Quality Control Applications" A. I. Peterson, R. C. A.
March 19, 1947:
"Optical Projection"
E. C. Polidor, Eng. Spec. Co.

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Sampling Plans for Verifying Clerical Work

HOWARD L. JONES

ILLINOIS BELL TELEPHONE COMPANY

Objective

This article deals with sampling plans for verifying clerical work where the purpose of the verification is not primarily to detect and correct errors in work already completed, but rather to reveal promptly conditions calling for remedial action, and thus to help minimize the number of errors in work currently being performed. Interest centers chiefly in how to improve what is going to happen in the future, and not in correction of what has happened in the past.

Conditions Favorable to Sampling

A sampling plan for verifying clerical work may be employed to best advantage under the following conditions:

a. The work can be divided into units of substantially the same kind. High grade work that is difficult to measure will ordinarily not meet this requirement.

b. There is a large volume, or a continuous flow, of such units.

c. Each work unit can be classified as correct or incorrect. In what follows, an incorrect work unit will be referred to as a "defective unit," or more simply, a "defect" or "error."

d. Failure to detect every error is not too serious. A sampling plan will not result in the detection of every error.

I. DESIGNING A SAMPLING PLAN

Acceptance Level

Many types of clerical work are such that the number of errors relative to the volume of work performed can be reduced to a certain point without much adverse effect on production; in fact, a steady, even performance is often conducive to a high degree of accuracy. Insistence on even greater accuracy, however, may result in a considerable reduction in hourly production. In that case, if greater accuracy is necessary, it may be cheaper to obtain it by subsequently verifying the work and correcting the errors than to slow down the original work too much. In any case, it is necessary to arrive at some decision as to what level of accuracy in the original work is reasonable and desirable, taking into consideration both the damage resulting from the perpetration of errors and the effect on costs of trying to eliminate them. This level will be referred to as the "acceptance level," and will be expressed as the ratio, in percentage, of the number of defective work units (containing one or more errors) to the total number of work units performed.

For the initial installation of a sampling plan, the acceptance level should be set with a view to attaining the desired objective of effecting some improvement in the quality of the work. From an analysis of past performance, the experienced clerks whose production rate is satisfactory may be ranked with respect to percentage of defective work units, and the acceptance level may be tentatively set at the average performance of the best one-third of these clerks. Later, this level may be revised to a higher or a lower standard. Different types of work should generally have different acceptance levels. Also, it may be desirable to set one level for experienced clerks and another for beginners. It is theoretically possible to set the acceptance level at zero; but the cost may be excessive. As a practical matter, it is usually best to set the acceptance level at a mark that is attainable, sooner or later, by every one whose work is to be judged by that level.

Operating Characteristics

A good sampling plan provides definite rules for deciding whether or not the work is satisfactory with respect to accuracy. If the application of these rules to a particular sample leads to a favorable decision, the work will be regarded as "accepted." If the rules lead to an unfavorable decision, the work will be regarded as "not accepted."

Unfortunately, these decisions will sometimes be wrong. The element of chance involved in **taking** a sample may operate to yield a sample containing very few errors, when, actually, the quality of the work, on the whole, is poor, or, conversely, a sample containing a relatively large number of errors, when, actually, the overall quality of the work is good. For this reason, there is some risk that work will be accepted when the individual who performed it is actually making too many errors, and some risk that work will not be accepted when, on the whole, it is really satisfactory. It is important to have some conception of the size of the risks of making wrong decisions.

Table I shows the approximate risks for a particular sampling plan that will be described in the section headed "Group Sequential Sampling." The first line of this table shows that if, on the average, .3 per cent of the work units are in error, the plan will lead to acceptance of the work 98 per cent of the time, and will lead to nonacceptance 2 per cent of the time. If .6 per cent of the work units are in error, the work will be accepted 41 per cent of the time, and not accepted 59 per cent of the time. If .9 per cent of the work units are in error, the work will be accepted only 7 per cent of the time.

TABLE I
OPERATING CHARACTERISTICS OF SAMPLING PLAN I

Per cent Defective	Chance of Accepting the Work	Chance of Not Accepting the Work
.3	.98	.02
.4	.89	.11
.5	.67	.33
.6	.41	.59
.7	.23	.77
.8	.12	.88
.9	.07	.93
1.0	.04	.96

Figure 1 exhibits a curve, based on Table I, that shows the relationship between the per cent defective and the chance of accepting or not accepting the work. Each line in Table I is represented by a point on the curve, which is known as the "operating characteristic curve."

Choosing the Risks

Associated with every sampling plan there exists a unique operating characteristic curve. Moreover, it is possible to design a plan that will cause the curve to pass through, or approach very closely, any two selected points inside the rectangle in which the curve is drawn, provided one of the points is to the right of the other point and a sufficient distance below. In practice, this means that a decision can be made at the outset requiring the sampling plan to be such that when the per cent defective is at the acceptance level, the chance of accepting the work will be large—say .99, so that the risk of not accepting is only 1 in 100—and when the per cent is some larger specified number, the chance of accepting the work will be small —say .10.

The choice of the two points on the operating characteristic curve is a matter of business judgment. In exercising this judgment, however, it must be kept in mind that the lower the risks, the greater the amount of verification that will be required. For some types of sampling plans, the exact amount of verification can not be predetermined. However, the **average** amount of verification required per sample can be determined readily for each per cent defective on a given range. By plotting this relationship as a curve, the average amount of verification under

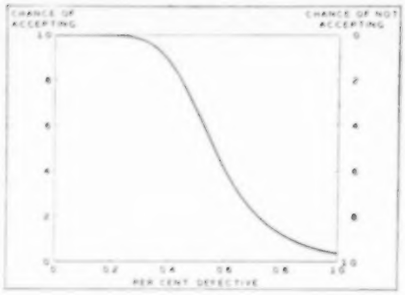

FIGURE 1—Operating Characteristic Curve for Sampling Plan I.

the worst possible circumstances can be found. Figure 2, for example, shows the average amount of verification per sample for the particular plan used in constructing Figure 1. Under this plan, the **average** number of units required to be verified per sample never exceeds 1620, reaching this maximum when the defective units are running about .55 per cent of the total work units performed.

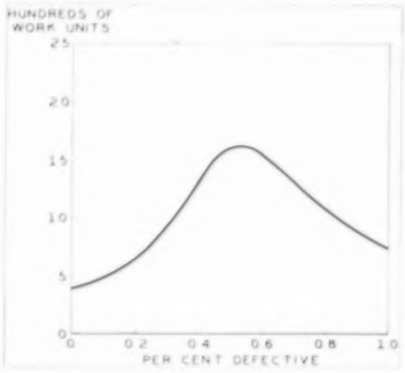

FIGURE 2—Average Amount of Verification for Sampling Plan I.

The problem of designing a verification sampling plan requires, initially, the specification of an acceptance level, a level of unacceptable work, and, at each level, a risk of making the wrong decision at that level. Once an acceptance level has been specified, a practical way to proceed consists of selecting an operating characteristic such that the risk of not accepting work is only .01 (that is, the chance of accepting is .99) when the per cent defective is at the acceptance level, and such that the risk of accepting the work is only .10 (that is, the chance of not accepting is .90) when the per cent defective is three times the acceptance level. The average amount of verification associated with the plan should then be computed. If the result indicates that the cost will not be excessive, the plan may be placed on trial. If the trial results are not satisfactory, however, the sampling plan should be revised until a suitable compromise is reached between the two objectives of minimizing the risks and minimizing the average amount of verification. The plan finally adopted will usually embody the choice of a middle ground between the plan that is most desirable from the protection point of view and the plan that is most desirable from the cost point of view.

Illustrative Problem

Perhaps the first application of a well designed sampling plan to the verification of clerical work was made by W. E. Deming several years ago in connection with the punching of tabulating machine cards in the Bureau of the Census. A similar application may be used to illustrate the problem of designing one of these plans.

In this application the work that is verified is the punching of Social Security numbers on tabulating machine cards for several thousand employees every month. The punching is subsequently verified 100 per cent by a machine matching procedure, but this verification is conveniently done some time later, after other information has been punched on the cards. Too many errors in the original work involves considerable expense in making corrections, and creates difficulties in summarizing tax data promptly.

The work unit in this case is the punching of a number on one of the cards. A defect, or error, is the incorrect punching of one or more digits in the number.

After a review of past performance on this work, the acceptance level was set at .3 per cent for the trial installation. When the percentage of errors averages between 0 and .3 per cent the work is considered to be good. When it averages between .3 to .9 per cent, the work is considered to be only fair. Anything beyond .9 per cent is poor. A sampling plan was desired such that when the average proportion defective is exactly .3 per cent, the chance of accepting the work will be about .99, but will be only .10 when the average proportion defective is .9 per cent. In other words, the chosen risks

were those corresponding to the points (.3%, .99) and (.9%, .10) on the operating characteristic curve.

Group Sequential Sampling

For the selected pair of points on the operating characteristic curve, there are several sampling plans that could be chosen. The type of plan known as "sequential sampling" results in the minimum, or very nearly the minimum, average amount of verification necessary to reach a decision as to whether or not the quality of the work is acceptable. This type, however, requires that counts be kept of the cumulative number of units verified and the cumulative number of defective units, and that reference be made to a chart or table after each unit of work is verified. These requirements make the plan expensive to use in connection with most types of clerical work. The type of plan discussed in this article is a modification designated as "group sequential sampling." When the selected pair of points on the operating characteristic curve has been specified, the design of a group sequential plan is simply a matter of applying the formulas given later on in Part III.

Table II illustrates the group sequential plan designed for verifying the punch card operation. In using this plan 200 units of work are selected and verified. If as many as 5 defects (incorrect work units) are found in this group of 200, the work is classified as unacceptable and verification ceases. If the number of defects in this group is 0, 1, 2, 3, or 4, however, another group of 200 units is selected and verification continues. If no errors are discovered in either the first or second groups—that is, if the total number of defects when 400 units have been verified is 0, the work is considered to be satisfactory and verification ceases. On the other hand, if the total number of defects becomes as large as 6 on or before the complete verification of the second group of 200 units, the work is classified as unacceptable and verification ceases. If the cumulative number of errors is 1, 2, 3, 4, or 5 when 400 units have been verified, a third group of 200 units is selected, and so on. Verification continues in this manner until one of the following two events occurs:

TABLE II
SAMPLING PLAN I

Cumulative Number of Work Units Verified (N)	Accept if No. of Defects is Equal to, or Less Than - (A)	Verify One More Group if No. of Defects is Equal to - (D)	Do not Accept if No. of Defects is Equal to, or More Than - (U)
200		0 - 4	5
400	0	1 - 5	6
600	1	2 - 6	7
800	2	3 - 7	8
1000	3	4 - 8	9
.....	....	.....	..

1. The cumulative number of units verified and the cumulative number of defects correspond to the numbers appearing in columns (N) and (A) on the same line of the table. In that event, the work is acceptable and verification ceases.

2. The cumulative number of defects reaches a number shown in column (U) when the corresponding number of units verified is equal to or less than the number shown in column (N). In that event, the work is unacceptable and verification ceases.

In this connection, note that a decision that work is unacceptable may be taken before completely verifying a selected group of 200 units. For example, if the first 5 units are defective, the work is immediately labeled unsatisfactory without verifying the remaining 195 units in the group.

The group sequential plans designed as outlined in this article will all be such that the groups are of equal size, and such that the numbers in columns (A) and (U) increase one at a time. These properties are important in facilitating the selection of the work to be verified and in keeping count of the cumulative number of work units verified and the cumulative number of defects. If the sampling plan is set up in groups of 200 work units, for example, individual groups may be selected by weighing, measuring, or some similar device. Extreme accuracy in the count is not necessary; groups of the approximate size required can usually be selected by mere inspection, with an occasional check to prevent too large discrepancies.

For convenience, the group size may be adjusted to some round number, such as a multiple of 5, 10, or 25, or it may be adjusted to the nearest multiple of the number equivalent to an ounce of tickets, or one-half inch of cards, where scales or measuring sticks are used in determining group size. In the tabulating card problem, the group size was rounded off from 183 to 200 units, the final result being the plan here designated as Sampling Plan I and outlined in Table II. This rounding off, however, reduces the chance of accepting the work below what was originally specified, as can be seen by referring to Table I; that is, the chance of accepting work when the per cent defective is .3 turns out to be about .98 instead of .99, and the chance of accepting work when the per cent defective is .9 turns out to be about .07 instead of .10.

II. ADMINISTERING A SAMPLING PLAN

Selecting the Sample

The successful operation of a sampling plan depends upon both good design and wise administration. Moreover, a plan cannot be well designed without knowing how it is to be administered, nor wisely administered without knowing how it was designed.

Wherever practicable, each sample should be selected entirely from the work of one clerk. If the same clerks perform a number of different kinds of work, each kind should be verified separately, using the sampling plan appropriate for that type of work. It should be kept in mind that the purpose of verifying a sample of the work is not primarily to determine the number of errors for that particular sample, but rather to arrive at a decision as to whether or not, hour after hour and day after day, a particular clerk is making too many errors.

Ordinarily a consecutively performed segment of work will provide a representative sample. However, individual units can be selected in random fashion from all parts of the work, if there is any reason for suspecting stratification. In any case, the clerk performing the work should not be in a position to know in advance which work will be verified and which will not.

Recording and Analyzing the Errors

The sample work units should be examined for accuracy by someone who possesses a thorough knowledge of how the work should be performed, who is careful and conscientious in verifying the work, and who will exercise unbiased judgment. Each error should be recorded in such a manner that it can be easily located afterward in case it becomes desirable to discuss the accuracy of the work with the one who performs it. A notation should be made as to the nature of the error as an aid in analyzing the cause. The results of the sample verification should be reviewed promptly, and, so far as possible, any errors recorded should be classified as "systematic" or "accidental." A systematic error is one that results from a lack of understanding as to how the work should be performed. Accidental errors are those resulting from inattention, fatigue, and like causes. The classification of doubtful cases requires judgment and experience.

Remedial Action

When systematic errors are detected in verifying a work sample, or when the total number of errors is so large that the work is classified as unacceptable, remedial action should be taken promptly in order to prevent the continued occurrence of avoidable errors. The extent to which work already performed should be verified under these circumstances is a matter of business judgment, and depends upon the seriousness of not finding the errors. The objective is the establishment of the habit of accuracy as quickly as possible.

Systematic errors are likely to be due to faulty instruction. They occur most frequently when a person has difficulty in understanding or performing the work due to impairment of sight or hearing, nervousness, or mental sluggishness. In some of these cases it may be advisable to change the work assignment, or to recommend that a physician be consulted. In most cases the nature of the errors should be explained to the person making them, and care taken that the explanation is clearly understood. Also, if the previous instruction was fairly recent, the instructor should be apprised of the situation with a view to eliminating future misunderstandings.

Accidental errors may be occasioned by poorly designed work papers, poor lighting or ventilation, noisy or defective office equipment, improper seating, bad posture, impaired eyesight, illness, improper eating habits, undernourishment, emotional strain, mental or physical fatigue, inexperience or carelessness. Continual effort should be exerted to see that working conditions are conducive to accuracy. Errors due to carelessness, or to conditions within the control of the person performing the work, should be brought to that person's attention promptly if the number is sufficiently large to cause the work to be classified as unacceptable.

In no case should remedial action be taken if the errors are all of the accidental type and the number is small enough for the work to be accepted. Moreover, if the errors are due to some temporary emotional upset, or to inexperience, it is sometimes better not to mention the errors to the person who made them, even if the work must later be verified one hundred per cent.

Verification Intervals

After remedial action is taken, subsequent verification with the same sampling plan should be made from time to time. A suggested schedule is shown in Table III.

TABLE III

VERIFICATION INTERVALS

0
2 hours
1 day
1 week
1 month

The first entry in the table means that the first work performed after remedial action is taken should be verified at once, using the regular sampling plan. If the work is accepted, a second verification should be made about two hours later. If the work is again accepted, a third verification should be made about one day after the second verification; a fourth verification about one week after the third verification; and a fifth verification after about one month has elapsed. Thereafter, the work should be verified at intervals of about a month. If remedial action is necessary at any time, however, the sequence of intervals should begin all over again. For example, if the third verification indicates that there are too many errors or errors of a systematic type and remedial action is taken at that point, further verification should be made of the first work subsequently performed, and again after two hours, one day, one week, and one month.

The same schedule might be used for new clerical workers, or workers new at the particular job, the first verification to be made of the first work performed after instruction has been given and the work is done independently. Judgment should be exercised, however, in deciding whether to take action in connection with the first work of a new employee, or the first work after previous remedial action.

Effect of a Short Verification Interval

Sampling a particular lot of work units twice has the effect of changing the risks. To illustrate, Table I shows that if .6 per cent of the work units are defective, the chances that this work will be accepted are about 41 in 100 for that particular sampling plan. If two samples of the work are taken, however, the chances are about 17 in 100 that the work will be accepted both times. In general, taking two samples of the same work, squares, and therefore reduces, the chances of acceptance, as shown in Table IV.

Similarly, if three samples of the same work are taken, the chances of accepting the work all three times are found by cubing the chances of accepting on the basis of but one sample. If the chances of accepting with one sample are 41 in 100 when .6 per cent of the work units are defective, the chances of accepting with

TABLE IV

RISKS FOR TWO SAMPLES OF THE WORK, PLAN I

Per cent of work defective	1 Sample Chance of accepting the work	2 Samples Chance of accepting both times	2 Samples Chance of not accepting at least once
.3	.98	.96	.04
.4	.89	.79	.21
.5	.67	.45	.55
.6	.41	.17	.83
.7	.23	.05	.95
.8	.12	.01	.99
.9	.07	.00+	1.00−
1.0	.04	.00+	1.00−

every one of three samples of the work are only about 7 in 100. In practice, this means that if the interval between verifications is short, the risk of accepting inaccurate work can be increased somewhat. Such work may have a good chance of passing the test once, or even twice; but soon a sample will be found that indicates the need for remedial action.

Records of Remedial Action

A running record should be maintained for each clerk whose work is verified, showing the dates, the conclusion, and the remedial action taken. A suggested form of record is a 3" x 5" card, illustrated in Figure 3.

Commendation

People should be commended for accurate work when the evidence is sufficient to warrant the inference that the work is actually accurate. However, some care is advisable in drawing such inferences. Suppose, for example, that work is considered to be good, fair, or poor with respect to accuracy according to whether the percentage of defective units averages from 0 to .3, .3 to .9, or .9 to 1.0, respectively. Suppose that Sampling Plan I, illustrated in Table II, is used in the verification of this work. Then if a single sample verification results in a decision to accept we may infer that the work is not poor, since Table I shows that the risk of accepting poor work is .07 or less. But an inference that the work is good is not warranted on this evidence alone, since the risk of accepting work that is only fair may be as large as .98.

If the sample verification results in the detection of no errors, however, the evidence of good work is much better, since the chance of selecting 400 work units without a defect is about .3 when the percentage defective is .3. If two successive samples contain no errors, the evidence is still better, since the chance of selecting 800 work units without an error is only about .09 when the percentage defective is .3. It would therefore be sensible to commend the work every time two successive samples are found with no errors in either sample.

Name of Clerk	Jane Doe		
Date of Verification	7/12	7/13	7/20
Accepted	+	+	
Not Accepted			—
Remedial Action			7/20
Nature of Action	7/20 Posture corrected		

FIGURE 3—Record of Remedial Action

Cooperation

The people who do the original work, as well as those who verify it, should have a clear understanding of the purpose of the verification and how the results can be used to attain greater accuracy. The sampling plan that is used, the manner of arriving at decisions, and the risks involved should be explained in a general way. The project should be presented as a tool that is helpful both to management and to the clerical force in doing a better job. Accuracy is the joint responsibility of the people who do the work and the people who supervise it. Teamwork is essential to achieve the best results.

III. FORMULAS

Group Sequential Sampling Tables

Anyone who knows how to use a table of common logarithms (to the base 10) can make the necessary computations for designing a group sequential sampling plan, construct the operating characteristic curve, and find the average amount of verification per sample. The problem of setting up a sampling table will first be discussed.

Suppose the risks have been chosen as outlined in Part I. Let $(p_1, 1-\alpha)$ and (p^2,β) be the two chosen points on the operating characteristic curve; that is, suppose that a sampling plan is to be designed such that when the proportion defective is p_1, the risk of not accepting the work is α, and such that when the proportion defective is p_2, the risk of accepting the work is β. (It is assumed that p_2 is larger than p_1 and that α and β are each less than $\frac{1}{2}$). Then it is first necessary to compute

$$g_1 = \log\ p_2/p_1$$
$$g_2 = \log\ (1-p_1)/(1-p_2),$$
$$a = \log\ (1-\beta)/\alpha,$$
$$b = \log\ (1-\alpha)/\beta,$$
$h_1 = b/(g_1+g_2)$, to the nearest whole number,
$h_2 = a/(g_1+g_2)$, to the nearest whole number,
$N_1 = (g_1+g_2)/g_2$, to the nearest round number,
$$s = 1/N_1.$$

(By a "round number" is meant a convenient number, such as a multiple of 5, 10, or 100, or the number corresponding to an ounce in weight or an inch in thickness. Too much rounding off may be undesirable, however. See Section on "Group Sequential Sampling" in Part I.)

The next step is to design a table with column headings as in Table II, and enter the value of N_1 on the first line in column (N). The numbers obtained by multiplying N_1 by 2, 3, 4, etc. are entered on the succeeding lines, as illustrated.

In Column (A) enter 0 on the line that corresponds to h_1; for example, if $h_1 = 1$, enter 0 on the first line. If $h_1 = 2$, enter 0 on the second line, as in Table II. On each successive line write the number obtained by adding 1 to the line above; for example, if 0 appears on the second line, write 1 on the third line, 2 on the fourth line, etc.

In column (U), write the number equal to $h_2 + 1$ on the first line. For example, if $h_2 = 4$, enter 5 on the first line in column (U), as in Table II. For each succeeding line add one to the number on the line above.

In column (D) write all the whole numbers that are larger than the number in column (A) but smaller than the number in column (U). If there is no number in column (A), the smallest number to be entered in column (D) is 0.

To illustrate, suppose a group sequential plan is to be so designed that when the number of defects is 18 per 1000, the chance of not accepting the work is only 1 in 100; and so that the chance of accepting the work is 1 in 10 when the number of defects per 1000 is 3 x 18, or 54. The specifications may be written

$$p_1 = 1.8\% = .018,$$
$$p_2 = 5.4\% = .054,$$
$$\alpha = .01;\ \beta = .10.$$

Compute

$$g_1 = \log (p_2)/(p_1) = \log 3 = .4771$$
$$g_2 = \log (1-p_1)/(1-p_2) = \log .982/.946 = .0162,$$
$$a = \log (1-\beta)/\alpha = \log .90/.01 = 1.9542,$$
$$b = \log (1-\alpha)/\beta = \log .99/.10 = .9956,$$
$$h_1 = b/(g_1+g_2) = .9956/.4933 = 2,$$

to the nearest whole number,

$$h_2 = a/(g_1+g_2) = 1.9542/.4933 = 4,$$

to the nearest whole number,

$$N_1 = (g_1+g_2)/g_2 = .4933/.0162 = 30,$$

to the nearest round number,

$$s = 1/N_1 = 1/30 = .0333.$$

Following the rules given above, leads to the numbers shown in Table V.

TABLE V
SAMPLING PLAN II

(N)	(A)	(D)	(U)
30		0-4	5
60	0	1-5	6
90	1	2-6	7
120	2	3-7	8
.....	....	.....	....

Operating Characteristic Curve

To construct the operating characteristic curve, compute various values of p, the fraction defective, from the formula

$$p = (10^{ts} - 1)/(10^{t} - 1),$$

where the values of t are chosen so that the resulting values of p are those within the range of greatest interest. Also compute the chance of accepting the work for each of these values of p by using the same values of t to find

$$L_p = (10^{th_2} - 1)/(10^{th_2} - 10^{-th_1}),$$

where L_p is the chance of accepting the work. (The numbers 10^{ts}, 10^{t}, 10^{th_2}, and 10^{-th_1} are obtained by finding the antilogarithms of ts, t, th_2, and $-th_1$, respectively.) Lay off a suitable scale of p values on a horizontal axis and a suitable scale of L_p values on a vertical axis. Then the corresponding values of p and L_p found from the above formulas may be paired and plotted as points which, when connected smoothly, yield the operating characteristic curve.

The computations of p and L_p are illustrated in Table VI. Observation of the values of p and L_p corresponding to $t = .5$ and $t = -.5$, shows that the operating characteristic curve closely approaches the points (.018, .99) and (.054, .10) that were originally specified.

Average Amount of Verification

The average amount of verification required by a group sequential plan is given by

$$n_p = [L_p(h_1+h_2) - h_2]/(s-p)$$

provided the verification ceases as soon as it is possible to reach a decision. Suppose, for example, that in using Table V a sample of 30 units is taken, and that the first 5 units are defective, so that only these 5 units are verified before reaching a decision that the work is unacceptable. In this case the sample size is 30, although the

TABLE VI

COMPUTATION OF p AND L_p FOR SAMPLING PLAN II

t	10^{ts}	10^{t}	p	10^{th_2}	10^{-th_1}	L_p
1.0	1.07978	10.00000	.0089	10,000.00	.01	.9999
.9	1.07152	7.94328	.0103	3,981.07	.02	.9998
.8	1.06333	6.30957	.0119	1,584.89	.03	.9994
.7	1.05520	5.01187	.0138	630.957	.04	.9985
.6	1.04713	3.98107	.0158	251.189	.063	.9963
.5	1.03912	3.16228	.0181	100.000	.100	.9910
.4	1.03118	2.51189	.0206	39.8107	.1585	.9788
.3	1.02329	1.99526	.0234	15.8489	.2512	.9520
.2	1.01547	1.58489	.0264	6.30957	.39811	.8982
.1	1.00770	1.25893	.0297	2.51189	.63096	.8068
0	1.00000	1.00000	.0333*	1.00000	1.00000	.6667*
- .1	.99235	.79433	.0372	.39811	1.58489	.5072
- .2	.98477	.63096	.0413	.15849	2.51189	.3576
- .3	.97724	.50119	.0456	.06310	3.98107	.2391
- .4	.96977	.39811	.0502	.02512	6.30957	.1551
- .5	.96235	.31623	.0551	.01000	10.00000	.0991
- .6	.95499	.25119	.0601	.00398	15.8489	.0629
- .7	.94769	.19953	.0653	.00158	25.1189	.0398
- .8	.94044	.15849	.0708	.00063	39.8107	.0251
- .9	.93325	.12589	.0764	.00025	63.0957	.0158
-1.0	.92612	.10000	.0821	.00010	100.0000	.0100

*For t = 0, p = s and $L_p = h_2/(h_1+h_2)$.

number of units verified is only 5. It is clear that for a large number of samples the average number of units verified will tend to be less than the average number of units selected. The value of $\bar{n}_p$ obtained from the formula given above is the average amount of verification for a very large number of samples, and not the average number of units selected.

Table VII illustrates the computation of $\bar{n}_p$ for Sampling Plan II. As indicated in the table, the values of L_p and p are taken for each value of t used in constructing Table VI to find the corresponding value of $\bar{n}_p$. The values of p and $\bar{n}_p$ may then be paired and plotted as points on a curve similar to that shown in Figure 2.

TABLE VII

COMPUTATION OF $\bar{n}_p$ FOR SAMPLING PLAN II

t	p	L_p	$L_p(h_1+h_2)-h_2$	s-p	$\bar{n}_p$
1.0	.0089	.9999	1.9994	.0244	82
.9	.0103	.9998	1.9988	.0230	87
.8	.0119	.9994	1.9964	.0214	93
.7	.0138	.9985	1.9910	.0195	102
.6	.0158	.9963	1.9778	.0175	113
.5	.0181	.9910	1.9460	.0152	128
.4	.0206	.9788	1.8728	.0127	147
.3	.0234	.9520	1.7120	.0099	173
.2	.0264	.8982	1.3892	.0069	201
.1	.0297	.8038	.8228	.0036	229
0	.0333	.6667	.0000	.0000	248*
- .1	.0372	.5072	- .9568	-.0039	245
- .2	.0413	.3576	-1.8544	-.0080	232
- .3	.0456	.2391	-2.5654	-.0123	209
- .4	.0502	.1551	-3.0694	-.0169	182
- .5	.0551	.0991	-3.4054	-.0218	156
- .6	.0601	.0629	-3.6226	-.0268	135
- .7	.0653	.0398	-3.7612	-.0320	118
- .8	.0708	.0251	-3.8494	-.0375	103
- .9	.0764	.0158	-3.9052	-.0431	91
-1.0	.0821	.0100	-3.9400	-.0488	81

*For $t = 0$, $\bar{n}_p = h_1h_2/(s-s^2)$.

References

The formulas for constructing a group sequential plan and finding values of p, L_p, and $\bar{n}_p$, are derived from those given by A. Wald in "Sequential Method of Sampling for Deciding between Two Courses of Action," **Journal of the American Statistical Association,** Vol. 40 (1945), pp. 277-306. See also **Sequential Analysis of Statistical Data: Applications,** Columbia University Press, 1945.

In this connection, observe that four quantities (p_1, p_2, α, and β) are used to compute only three parameters (h_1, h_2, and s) of the desired sampling plan. This means that there are infinitely many pairs of p_1 and p_2 that result in the same sampling plan, and that it is possible to choose any pair at will for the purpose of computing the operating characteristic curve and the average amount of verification. In particular, values of p_1 and p_2 may be chosen that correspond to $g_1 + g_2 = 1$. As a consequence, g_2, a, and b may be replaced by s, h_2, and h_1, respectively, in computing p, L_p, and $\bar{n}_p$.

Indirect Calibration of an Electronic Test-Set

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In measuring certain electrical characteristics of electronic tubes, it is essential to have a simple, efficient method of calibrating the test-sets which are in continuous use by production inspectors on the factory floor. There is no fundamental standard which can be carried from one test-set to another, and the usual procedure in the tube industry has been to attempt a comparison between individual test-sets and a standard bridge which is located in a separate Measurements Laboratory by the intermediate use of "standard" tubes. The bridge itself is calibrated by a laborious method which requires a great deal of time, and the technique is not a practical one for the different test-sets located in the factory.

The comparison procedure previously in effect to calibrate a test-set which measures transconductance (G_m or S_m) had been to select five "standard" tubes which had been "aged" to assure reasonable stability and whose readings were within the specification limits of the particular tube-type. These five standard tubes were read on the bridge and the readings were recorded on form-sheets, one for each test-set. The tubes were then taken to each of the floor test-sets

where the tubes were read again and the readings recorded on its form-sheet. From a series of these form-sheets, the responsible persons attempted to see some pattern which would permit satisfactory adjustment and maintenance of the test equipment. This "form-sheet method" is a general one used frequently by engineering, production, and management to "maintain" control of a process.

Some three years ago there was a general and serious lack of confidence in the reliability of the factory G_m test-sets which were being used in one plant of National Union Radio Corporation. Large quantities of tubes were involved and the situation was serious. Inaccurate test sets could give a stamp of approval to non-conforming tubes from the daily production and could reject tubes conforming to specifications. But an even more serious situation resulted which affected the effort expended to improve the quality of tubes during manufacture. Those persons responsible for the accuracy of the test-sets insisted that the test-sets were not seriously in error, but that the tubes were of poor quality and were fundamentally to blame for the variations in readings which were being experienced. So long as a lack of confidence could be charged to the reliability of test-equipment, the design engineers and production men could claim that there was no reason for effort on their part to improve the quality of the tubes. With tubes to be tested worth thousands of dollars daily, it was urgent that immediate action be taken to determine the situation and to devise a more efficient criterion for calibration control than a glance at each new form-sheet as it came along.

It was generally agreed that there might be a great deal of variation in the reliability of a test-set over a period of a few days and that voltage conditions could gradually produce increasing errors in a set. Furthermore, changes in temperature and humidity were expected to produce fluctuations. A quality control chart using the average $\bar{X}$ and the range R in some way was thus indicated as being desirable, and the original comparison technique between the bridge and the test-sets with five standard tubes was modified to permit the use of these charts. There was a combination of reasons for continuing to select five different standard tubes rather than making five different readings on one tube.

(1) It was more than theoretically possible that a test-set might be adequately calibrated at one position on the scale and be significantly in error elsewhere within the specifications. In other applications of this indirect calibration method, and in a refinement of this one, it may be sufficiently important to select standard units which measure near each specification limit and additional ones spaced over the spread of the specifications. Additional refinements of the technique could include an analysis of the measuring instrument variation by separate control charts at each of several different magnitudes of the measurement.

(2) It was known that internal variations within a tube would produce appreciable variations in G_m readings at some unpredictable time in the future, and that valuable time would then be lost in ascribing the change to the tube or to the test equipment.

It is important to realize that there was general and justified confidence in the reliability of the bridge; in fact, there were data to indicate that the bridge would not vary by more than a fraction of a per cent from day to day.

In the modified procedure, each of five standard tubes was read on the bridge and then on each floor test-set and the readings were recorded on a modification of the original form-sheet. The **difference** between the set reading and the bridge reading for each tube was then determined, and the average $\bar{X}$ and the range R of these five differences were computed. Plus and minus signs were used to indicate whether the set read higher or lower than the bridge, respectively, as in the following example:

TABLE 1

Standard Tube No.	Reading on Bridge	Reading on Test Set #1	Difference
1	1820	1960	+140
2	2590	2660	+ 70
3	2370	2360	— 10
4	2030	1930	—100
5	1760	1840	+ 80
			$\bar{X}$ = + 34,
			R = 240

A variables control chart of these differences was then constructed and maintained experimentally at one test-set; readings of the standard tubes were taken every two hours. Within a few days we had control charts of the same type at the other test-sets on the floor. An example of one of the control charts is shown in Figure 1. After a short experience, several things became apparent. Certain test-sets were unreliable and it was impossible to obtain satisfactory performance from them without a major overhauling, while a much improved performance of others could be obtained fairly easily by making relatively minor systematic adjustments with the control charts as guides. It was learned that remedial attention could be given to a test-set in advance of serious trouble, and the trends which had been predicted occurred rather frequently.

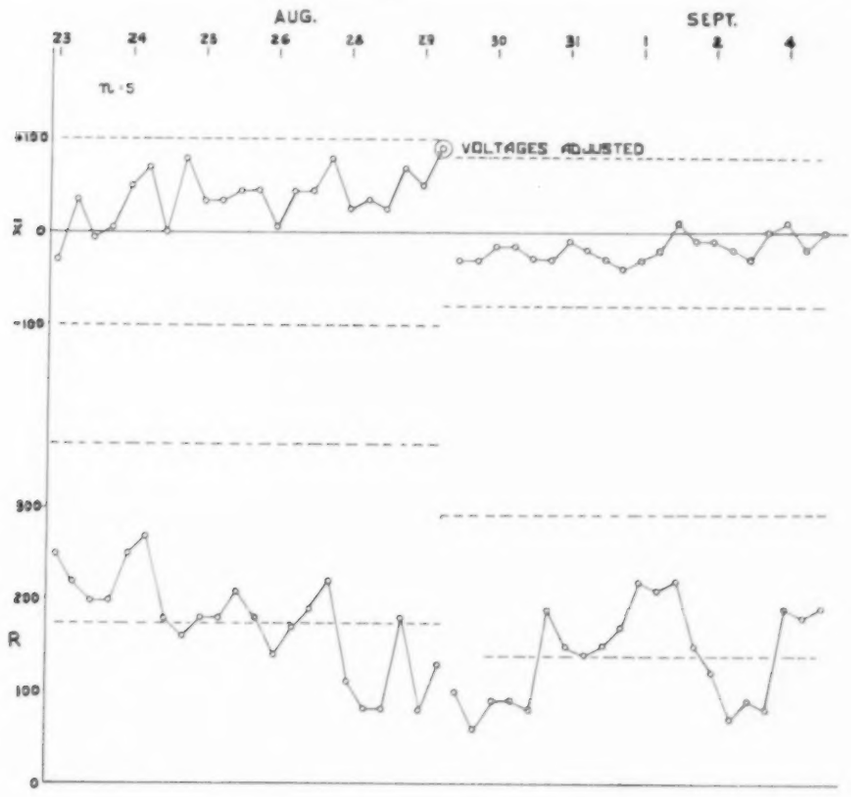
One of the first interests was to compare the performance of the test-sets obtained in conjunction with the control charts with the earlier performance which had occasioned so much dissension. Data from previous months were available and they were analyzed by the same control chart technique over a two-week period in June (which was prior to the control chart technique). The data given below compare the performance of six test-sets over the June period with a two-week period in August (a few days after the start of the control charts), and a two-week period in November after additional experience had been gained.

TABLE 2

Set No.	June 1-15 $\bar{\bar{X}}$	June 1-15 $\bar{R}$	Aug. 15-30 $\bar{\bar{X}}$	Aug. 15-30 $\bar{R}$	Nov. 1-15 $\bar{\bar{X}}$	Nov. 1-15 $\bar{R}$
1	— 63	181	— 6	72	17	74
3	— 86	164	— 1	68	— 1	68
5	— 62	216	—12	61	—13	61
6	— 47	202	9	74	7	75
7	—136	138	16	86	17	140
8	— 92	186	2	81	3	92

The immediate improvement effected in August is apparent both by the improved level of $\bar{\bar{X}}$ and the reduced variability of the sets as represented by $\bar{R}$. It was soon discovered that Set No. 7 was in need of a major overhauling. No absolute criteria had been established as to allowable limits of variation of the test-sets with respect to the bridge, but it was agreed in advance of the experiment that it would be satisfactory and a decided improvement to maintain the average of five tubes within 5% of the bridge readings. It was found during the first weeks of the experiment that the average of five tubes could be held within 4% of the bridge for most sets, and even closer agreements were obtained subsequently; the variation had been in excess of 10% during the first two weeks in June. In general, three sigma control chart limits were selected which represented the best performance of each test-set and were projected in advance on the charts for both $\bar{\bar{X}}$ and R. Appropriate action was indicated if a point exceeded these limits or if a significant trend developed.

Since the bridge was the accepted standard, the desired level of the average difference is $\bar{\bar{X}} = 0$. It was a surprise to learn that the earlier calibration procedure had failed to maintain adequately the average of the test-sets with respect to the bridge and this condition was relatively easy to remedy.



It was even more surprising to find such large values of the range. It was possible to explain this wide range by any of the following three assumptions which revert, essentially, to the original "tube versus test-set" controversy:

(1) The five standard-tubes were stable; the variations in readings arose from the inability of a test-set to duplicate its own readings. This assumption certainly had some merit as evidenced by the data of Table 2. In particular, the value of $\bar{R}$ for Set No. 7 in November was significantly larger than for other sets; this difference continued in subsequent performance, thus refuting earlier data which failed to indicate any lower quality performance of Set No. 7. The causes which produced trends in the $\bar{\bar{X}}$ chart (see Figure 1) or an upward trend in the R chart of one test-set only were obviously assignable to the particular test-set.

(2) The test-sets were reliable; the variations in readings resulted from unpredictable internal variations within the standard tubes. This assumption had merit also, and the most obvious variations resulted in the replacement of one of the five standard tubes by a new one from a reserve pool of standard tubes kept for that purpose. A need for replacement was most often evidenced by an upward trend of several different R charts. Such a trend could not be attributed necessarily to the standard tubes, (an alternative might possibly be general weather conditions) but analysis of recent bridge readings from the form sheets on individual tubes showed clearly whether or not one particular tube was the assignable cause.

(3) A combination of assumptions (1) and (2). The previous discussion indicates the existence of this joint responsibility. It was most convenient to have data from several test-sets in order to compare their behavior. If data had not been available from at least three different test-sets, additional regular sets of readings from the bridge (on the same standard tubes) would have been more than satisfactory and such readings would have been desirable in this application; they were essentially impossible to obtain since the ex-

isting demands on the bridge were already excessive.

After the merits of this control chart technique had been demonstrated in one plant, it was decided to verify it in another of our plants where the test-sets were believed to be extremely reliable. The engineer in charge of test-sets started his control charts from data already in his possession and which had been used in his regular calibration. It developed that the control charts showed wide fluctuations which represented unsuspected variations in the test equipment and that the general confidence in the test-set performance had not been warranted. Control charts were then posted at each of his test-sets; in subsequent operation he was able to predict and prevent serious difficulties as trends developed on the charts and was able to improve materially the performance of the sets.

The advantages of control charts using differences in any other similar indirect calibration program over an attempt to control performance of the measuring device by scanning a series of form-sheets are essentially the same as the advantages of any control chart over a series of figures. Other attempts in the tube industry to improve upon the form-sheet scanning procedure had included the maintenance of graphs either for individual tube-readings from each test-set and the bridge or for the average of the five tube-readings. But such procedures are more work than control charts with differences and are much less effective. The difference control chart is applicable to a wide variety of calibration techniques now in operation in many different industries which use a sample of the manufacturer's product as an intermediary between inspection test instruments and the more fundamental and reliable instruments, where the two sets cannot be compared directly.

Note: This application of control charts with differences is fundamentally similar to the very interesting example discussed by Lieutenant-Colonel Frank E. Grubbs*. However, Lieutenant - Colonel Grubbs was concerned primarily with a judgment of the product which was being offered for acceptance, it not being mandatory to establish absolute calibration corrections for his measuring devices. His comparisons were made between samples from a standard uniform product and samples from a product which was being offered for acceptance. Our control charts were designed to control the reliability of our test-sets and the technique offered no judgment directly with respect to the quality of the product itself; the technique performs the important function of establishing reliability of measurement so that improved judgment can be made on the quality of the product.

Since the variations in the bridge were small, the initial technique was justified in neglecting the bridge variations; we computed 3σ limits on our $\bar{X}$ and R charts by the standard methods described in **American War Standards Bulletin, Z1.3,** p. 39. In a refinement of this technique in other applications it may be desirable to obtain more accurate estimates, σ_f and σ_t of the fundamental standard and the inspection test-sets, and determine 3σ limits for the difference control charts for each test-set from the relation $\sigma = \frac{1}{\sqrt{n}}\sqrt{\sigma_f^2 + \sigma_t^2}$ This latter technique is the one used by Lieutenant-Colonel Grubbs.

* Lieutenant-Colonel Frank E. Grubbs, "The Difference Control Chart with an Example of its Use," Industrial Quality Control V. 3 July 1946, pp-22-25

Control Charts versus the Analysis of Variance in Process Control by Variables

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It has occurred rather frequently that statisticians on being introduced to the Shewhart control chart have reacted with the statement that an applicction of the analysis of variance would serve the same purpose and more effectively. To many of the members of the American Society for Quality Control who have had a recent introduction to statistical methods by way of the Shewhart control chart such a statement is likely to be disturbing. In manufacturing procedures generally they have been accustomed to using the more rather than the less efficient tools. Is it possible that the teachers who trained them to use the control chart really had something better for the job up their sleeves? A discussion of the relative merits of these two methods with a minimum of technicalities seems to be needed. Further, such a discussion must try to make the essential nature of both methods clear and ought to throw a great deal of light on them.

We will proceed by applying both methods to a very familiar and simple example; the one found on pages 12 and 13 of the American Standard Association Manual, "Guide for Quality Control and Control Chart Method of

Analyzing Data," (Z1.1 and 2). The control charts, for $\bar{X}$ and R and for $\bar{X}$ and σ are presented there in detail and we have only to point out what the analysis they provide really means. In the first place, the R's or the σ's furnish a measure of the **variation within samples.** Since the samples of 4 are consecutive items produced within a relatively short time interval, it is assumed that this within sample variability is essential process variability produced while the process is stable, "with a constant cause system." But it is important to note that this assumption is checked by putting control limits on the R or σ chart. If no individual R or σ is outside its limit lines then the behavior is what one gets if observed within sample-variability is only due to inherent process fluctuation. Then one may use $\bar{R}$ or $\bar{\sigma}$ to get an estimate of σ', the long run or true process variability.

Next having on hand a valid estimate of σ' one may use it to set limits on the variation $\bar{X}$'s may show if their fluctuation is also only due to inherent process variability. (The reader may recall that the tabular constants A_1 and A_2 are respectively based on estimates of σ' obtained from $\bar{\sigma}$ and $\bar{R}$). If the process is in statistical control, is stable, then the same constant cause system only is operative during the longer periods between samples. The variation one sees among $\bar{X}$'s on the $\bar{X}$-chart is **between sample variation.** The limit lines on the $\bar{X}$-chart are set from the within sample variation and the chart for averages with these control limits is essentially only a device for comparing the variation among samples with the variation within samples. If $\bar{X}$'s fall outside their limit lines, then the first variation is too great compared to the second and we have evidence of the presence of assignable causes operating in the periods between samples. Anybody who understands control charts will know that more than this can frequently be read from a chart but we will return to this point later.

The reader familiar with the analysis of variance will know that its application to this example also provides a comparison between the among sample variation with the within sample variation. Let us see how this is done in this case. First, it is assumed that the inherent process variability which is causing the observed fluctuation within samples is constant and the individual R's or σ's are controlled. Then σ'^2, not σ', is estimated by first taking the total sum of squared deviations within samples about their respective means. Then this total, obtained by pooling these squared deviations from all samples, is divided by a factor, known as the number of degrees of freedom, to give an estimate of σ'^2 which is on the average correct. Sample σ^2's are on the average smaller than σ'^2; the number of degrees of freedom here is the sample size less 1; that is, n—1, multiplied by the number of samples. In our example, this factor is 10 x 3.

Next if the process is in control from sample to sample, the variation of the $\bar{X}$'s will only be that due to inherent process variability. In that case we can get another estimate of σ'^2 from the among sample variation. This is obtained by taking the sum of squared deviations of the $\bar{X}$'s about their average, $\bar{\bar{X}}$, and dividing it by the appropriate number of degrees of freedom which is this time the number of samples less 1 (in our example, 9).

Now if the process is in control from sample to sample, then our two estimates of σ'^2 should differ only because of sampling effects. But if the second estimate is too large in comparison with the first; that is, if the among sample variation compared with the within sample fluctuation is too large, then again there is evidence of the presence of an assignable cause at work in the periods between samples. To decide when to draw this conclusion, one takes the ratio F of the second estimate by the first and then from tables one can estimate the chance that F should be as large as the computed value due simply to random sampling.
The arithmetic of the analysis is carried out as follows:

(1) Square the individual measurements and sum.

$8.4^2 + 7.1^2 + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots + 8.8^2 = 2650.75$

(2) Square the Total X for each sample, sum, and divide by 4, the sample size

$32.6^2 + 31.4^2 + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots + 33.0^2/4 = 2626.40$

(3) Sum the 40 individual measurements, square, and divide by 40.

$322.9^2/40 = 2606.61$

The analysis is then summarized in tabular form:

Source of Variation	Sum of Squared Deviations	Degrees of Freedom	Estimated Variance
Among samples	(2)—(3) = 19.79	9	2.20
Within samples	(1)—(2) = 24.35	30	0.812
Total	(1)—(3) = 44.14	39	.....

We have

$$F = 2.20/0.812 = 2.70$$

Referring to tables for F, we find that the chance that F should be as large as 2.70 purely by sampling accident is between 0.01 and 0.05. On the $\bar{X}$ chart there was one point outside the limit lines. A calculation of the chance that one or more points out of ten should be outside the limit lines by accident gives 0.027 and the agreement with the result from the analysis of variance is quite good.

Though the results by the two methods are in close agreement in this example, it is nevertheless true that the two procedures are not exactly equivalent. The analysis of variance is a summary method based on the overall variation among sample means while the control chart for averages is based on the behavior of individual X's. It can happen that no one $\bar{X}$ will fall outside the limit lines and the analysis of variance will disclose that too many of them are near the limit lines. On the other hand a single point on the $\bar{X}$ chart might be well outside the control lines and yet because the remaining

points are relatively near the center line the total sum of squares among averages will not be large enough for the analysis of variance to indicate lack of control. But in general, the two methods are nearly enough equivalent that both will disclose any clear case of lack of control among averages and when one says control is good the other will too.

Enough has been said already to make it evident that for process control by variables, as in the example considered, the use of control charts for R's or σ's and $\bar{X}$'s does possess some advantages over the use of analysis of variance. In particular, we have noted that the R or σ chart provides a means of judging whether or not the within sample variation is controlled so that one has justification for proceeding to estimate σ' from the data. But in using the analysis of variance, one in effect assumes that this control exists and by this method this assumption is not checked. This is important but in addition we must also point out other merits of the control chart system.

First as compared to the analysis of variance, it is both more readily understood and used. Second, and this is very important, the control chart is a visual device. Even people who have little grasp of the underlying principles can read in most cases the story told by $\bar{X}$ and R-charts. Third, the control chart is better adapted for maintaining a running check on the performance of a process which is, of course, almost essential to effective process control. Fourth, because we have limit lines drawn on the $\bar{X}$-chart, one identifies at once the out of control $\bar{X}$'s. After an analysis of variance reveals too much fluctuation among sample means, one still has to examine further the individual $\bar{X}$'s to try to determine at what point trouble made itself evident. Finally any experienced user of control charts reads from them a great deal more than that points are within limit lines or not. He gets information worth money to his shop that would be wholly or partly concealed in the purely tabular presentation of the results of an analysis of variance.

It may begin to appear that there is not much left that can be put on the credit side for the analysis of variance. But the latter has its points, too. A paramount feature is the fact that the analysis of variance is designed to get the maximum of information from a limited amount of data. If observations are costly, difficult, or time-consuming, then it becomes a prime consideration to use the most efficient statistical tools. There are two chief aspects of the analysis of variance which make it superior in such cases. Granting, as in many situations it can be, that the within sample variation is controlled, then the method of dividing the total sum of squares of deviations about the mean within samples by the number of degrees of freedom gives a better; that is, on the average closer, estimate of σ'^2, than the one obtained from $\bar{R}$ or $\bar{\sigma}$. This is less important in process control because it is usually easy to get plenty of observations. But of much more importance is the fact that our example has employed only the very simplest form of the analysis of variance. This was the proper form for data of that kind. We wished only to compare the variability due to a time effect with inherent process variability.

But suppose we were concerned with a dimension on machined parts which are coming off of each of the four spindles of an automatic screw machine. If it were suspected that there were spindle differences then control chart procedure is to keep a chart on each spindle. But if it could be assumed that each spindle has approximately the same uniformity, then a single analysis of variance can test for assignable causes due only to: (1) differences among the centers to which each spindle is working, and (2) to variation among samples taken at different times. The samples would consist of one or perhaps two pieces taken at the same time from each spindle and the method enables one to eliminate the time factor while studying the spindle effect and also to eliminate the spindle factor while looking for effects due to differences in time. The analysis of variance in this case would be a three component breakdown of the total variation instead of a two-component one. The agricultural experimentalist, to illustrate a more complicated use of the same general method, gets yields for different plant varieties under different fertilizer treatments grown in different kinds of soil. If the variability of yields for any constant set of these three factors can be assumed very nearly the same, then he can study the effect of any one of these factors or of any two of them in combination for constant values of the others without having to perform the almost impossible number of separate experiments required if each one or two factors were held experimentally constant.

It may be gathered that the analysis can have important industrial application, especially in laboratory work. But for the situations in process control for which $\bar{X}$ and R or σ charts have been advocated by Shewhart and other competent authorities, these charts as tools for the job more than hold their own in comparison with the analysis of variance.

REPRINTS AVAILABLE

The article appearing in the November, 1946 issue of INDUSTRIAL QUALITY CONTROL entitled, "A Sampling Procedure for Design Tests of Electron Tubes" by the Joint Electron Tube Engineering Council, Committee on Sampling Procedure composed of S. W. Horrocks, P. M. Dickerson, H. F. Dodge, E. R. Ott, H. G. Romig (alternate member), W. B. Rupp, J. R. Steen, R. E. Wareham, and A. K. Wright has attracted so much attention that reprints of the article have been prepared for distribution. The cost is 25 cents per copy in bulk or for single copies. Orders should be sent to Alfred L. Davis, Rochester Institute of Technology, Rochester 8, New York.

QUALITY CONTROL IN THE CHEMICAL INDUSTRY*

I: How Statistics Contributes to Quality Control in the Chemical Industry

CHARLES A. BICKING
HERCULES POWDER COMPANY

The Industry Discovers Quality Control

The chemical industry, like other industries, upon returning to its pre-war commercial operations has found in its plants a new set of tools, the quality control techniques. Within the few months of readjustment, rapid strides have been made in adapting these tools to the industry's basic problem of controlling chemical reactions.

Those who have been working with the methods are encouraged. Impartial observers are impressed by the progress being made and by potential economies in production and measurement. They think that the chemical and related industries are the most fertile fields for the expansion of the use of quality control in the near future.

*During 1947, INDUSTRIAL QUALITY CONTROL will present a series of articles dealing with the use of statistical control in the Chemical Industry. This introductory article by Mr. Bicking inaugurates the series. In succeeding issues articles devoted to the use of these techniques for acceptance and specification of materials, in the analytical laboratory, and in production control will be presented. Applications to specific industries will follow. The series will be concluded with a set of articles presenting such statistical techniques as correlation, significance tests, variance analysis, and sequential testing in the research laboratory and in production control.

This series is not intended to provide a complete course in the use of statistical control in the Chemical Industry. At the same time, the sequence of articles follows closely the order of presentation of the materials comprising the courses offered for the Chemical Industry by the Rochester Institute of Technology in June, 1946 at Rochester and in September, 1946 at Syracuse. The authors of the articles are the members of the faculty of those courses.

Laboratory and production men who have observed the advantages of statistical quality control methods believe that, eventually, a knowledge of them will be as much a part of the chemist's fitness for his job as his knowledge of operating procedures or of analytical methods.

Quality Control Fits In the Scheme of Things

This industry does not have an inspection function in the sense that it is known in mechanical processes. Quality is "built in", often in large homogeneous masses of material. After the ingredients have been proportioned and the controls set as carefully as possible, there is often little opportunity for inspection until the final product is pumped or dumped from the system. The control laboratory which analyzes the result is a far cry from the typical inspection department of a piece-part plant.

This subtle, yet important, difference means that all along the line responsibility for quality is heavy. The laboratory, as well as the technical and operating staffs of the plant, must use every means at their disposal to discharge that responsibility. The powerful tools offered by statistics ease this task.

Quality control is a proper function of management and support of the program in a plant must be forthcoming. However, at the level of action, the way of thinking about a process in terms of variability must be adopted. This approach, characteristic of quality control, is the way the laboratories can go beyond merely recording, after the fact, what the process did. It is the best way the operating men have of putting an end to reworking, blending, and grading down lot after lot.

The transfer of emphasis from weeding out defective material to making the material right in the first place is easy for the chemical industry. It is largely an accomplished fact because the industry thinks in terms of control. There is, for the most part, a ready acceptance of a new control tool when it is understood. The acceptance of quality control is based on the fact that it fits into the chemist's scheme for controlling processes so as to produce the right result consistently.

Adapting Standard Techniques to the Industry

We speak of adapting quality control to a process or industry. Actually, most of the adaptations in use were already well known to the statisticians and have merely been taken over from applications for which they were originally designed. During the war years, certain standard formulae and procedures were widely publicized and popularized in the mechanical industries. Active quality control programs, however, did not overlook the less generally discussed, but no less effective, adaptations of the basic techniques.

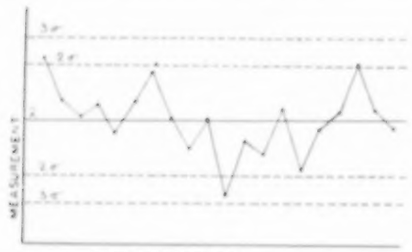
Some characteristic features of chemical processes slowed up development of quality control applications until the statisticians

were able to acquaint the practical men in industry with the real flexibility of the methods.

Batch Processes Offer a Challenge

The control chart is a basic tool and the approach to its use in analyzing batch operations will serve as an illustration of how chemical plants go about using quality control.

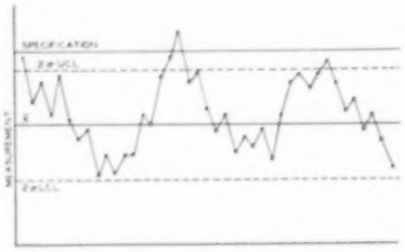
For example, in batch processes, characteristic of so much of the industry, it is difficult, if not impossible, to get a measure of "within" variability. Consequently, the grouping of batches, often separated widely in time, may produce a measure of variability with entirely different operational meaning than the measure arising from normally taken sub-groups. Thus, limits for this type of process tend to be relatively wide and the degree of control unusually good. It has been common practice, therefore, to use limits narrower than the standard 3-sigma limits.



SUB-GROUP NO.
TYPICAL AVERAGE CHART-BATCH PROCESS
FIGURE 1

The large time interval often involved means waiting too long to obtain sub-group averages for plotting. As a result, a great many of the charts in use are for individual batches. In this way, action can be taken before causes of variation are obscured by the passage of time. Sub-grouping is resorted to, in most cases, to obtain the necessary measure of variability and sometimes group averages are plotted as well as individuals to give a clearer indication of trends.

The choice of a rational sub-group in such situations dictates the use of very small groups. Since the smallest possible grouping is by twos, that size is frequently used. The small amount of data usually available from batch operations has led to the use of moving ranges of two, which is the most rapid means of accumulating enough sub-group ranges to give a reliable measure of variability. This is in accordance with theory, since use of the moving range merely gives the most rational sub-group according to the accepted definition of that term.

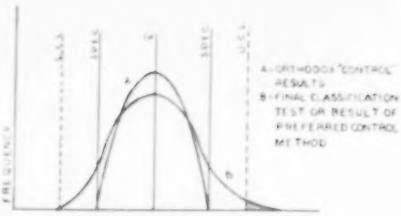


BATCH NO.
TYPICAL CHART-INDIVIDUAL BATCHES
LIMITS DERIVED FROM MOVING RANGES OF TWO
FIGURE 2

The Operational Meaning of "Control" Samples

In many batch processes, "control" samples are taken at intervals until an acceptable result is obtained. At that time the batch is considered to have reached its end point. The results of such a procedure, as would be expected, are almost always on-grade and usually exhibit good control. However, it often happens that when the same batches are given a final test for classification, specifications are exceeded and lack of control appears.

This demonstrates the fallacy of determining end points by successive "control" samples. This practice is prone to bias in sampling and also fails to take into account possible lack of precision in the test methods. A preferable method is to calculate feed, control conditions, and time cycle for the batch. Then the end point may be designated in terms of time, temperature, or liquid level. The "control" samples may thus be eliminated and only the final classification sample plotted on a control chart to detect any failure to produce the expected result. This means reduced testing and saving in processing time through elimination of delay. When action based on the charts makes possible a "state of control", a more faithful representation of the true character of the process has been obtained.



TYPICAL RESULT OF FINDING END-POINT
BY SUCCESSIVE "CONTROL" SAMPLES
FIGURE 3

The Importance of Precise Test Methods

The control of continuous processes follows more closely the pattern in common use in mechanical operations. The greatest exception is possibly that chemists are not used to sampling by sub-groups. Individual samples are apt to be taken at regular intervals during the day and if the only rational basis for sub-grouping is on a chronological scale, the problem of sub-group size comes up as in batch operations. Instead of four measurements on individual pieces taken from the production at a given time followed by four more taken at once an hour later, we may have four hourly samples followed by four more taken at the next four hourly intervals. This pattern is well established and will be hard to change. Moreover, the more or less homogeneous nature, at a given time, of a stream of liquid or a flow of viscous or dry material would give four simultaneous samples a different operational meaning than is customarily given them. The variation within the four would be most likely to be due to the test alone.

In both batch and continuous processes of a chemical nature, the precision of the analytical methods tends to be of greater relative importance than in mechanical processes. The reason is not always that chemical tests are less precise, though many such tests are notably lacking in sufficient precision to measure real differences in product. It possibly has as much to do with the expense of these analyses and the usual reluctance to make replications. One test is often used to represent the quality of large and very valuable masses of material. Much depends on how well the true quality is represented by the one meas-

urement. Thus, it is important to know that the analytical method is precise, or better, how precise it is. It is desirable to know how likely the precision is to be affected by weather conditions, by changes in reagents, or by differences between operators.

That is why standard samples are in such common use in the laboratories of the industry for comparison with day to day measurements on production lots. The quality control methods are invaluable in determining how reliable these standards are. Production charts are therefore often supplemented by laboratory charts for the standard sample.

Where the Methods Apply in the Industry

The importance of proper sampling and of precise analyses is so great that closer control of the production processes may have to await their achievement. Indeed, it is commonly accepted that quality control work in the reseach and analytical laboratories must go along with, if not precede, quality control applications to production procedures. Contrasted to a mechanical process where uniformity of a dimensional measurement is the object of quality control, a chemical process may offer many more opportunities for variability to enter into the end result. Figure 4 indicates the principal steps in a simple chemical process.

CHEMICAL PROCESS

(a) **Raw Materials**	(b) **Production Process**
1 Sampling error	1 Sampling error
2 Analytical error	2 Analytical error
3 Inherent variability of the raw material supply	3 Inherent variability of the process

MECHANICAL PROCESS

1 Sampling error

2 Error in making dimensional measurements

3 Inherent variability of the machine

FIGURE 5

Raw materials enter the plant and their purity must be reported on by the analytical or control laboratory. If satisfactory, they are fed through the manufacturing process. The product must be analyzed and classified before sale. The plant operators are interested primarily in the quality of the product but also are concerned with the yield that can be maintained and the progress the research laboratory is making in improving the process.

The factors which influence quality and yield are variability of the raw materials and the innate variability of the production process. The chemist attempts to obtain information on these variables by sampling followed by chemical analysis. There have been introduced, therefore, another set of variables by the sampling and analytical operations. It has been pointed out that due to the nature of chemical materials and analytical methods, these latter sources of variability may be so great as to mask the inherent variability of raw materials or processes. It is imperative that accurate measurement, rather than an opinionated estimate, be made of the magnitude of the sampling and analytical errors compared to the raw material or process variations.

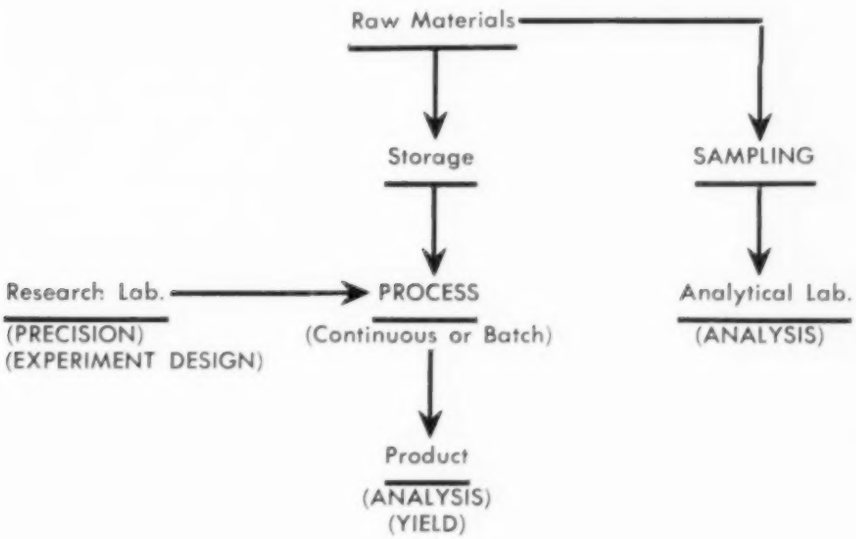


FIGURE 4

Chemical and Mechanical Processes Contrasted

In Figure 5, the variabilities which may be involved in chemical and mechanical processes are contrasted.

The mechanical engineer is fortunate in that his sampling errors are usually small and can, for practical purposes, be taken as negligible if the operation is performed properly. Occasionally, he is troubled by dimensional measurement, but most of the time the errors in measuring such properties as length can be taken as negligible. His measurements give him directly a truly representative picture of the performance of his machine. He has not had the complicating factors introduced into the problem facing the chemical engineer who must deal with three simultaneous variabilities.

The course of the mechanical engineer in adapting statistical methods has been proportionately simpler.

The chemical industry, however, must look to statistical analysis of sampling and analytical variabilities to obtain a true picture of product variability. A measure of analytical precision may be obtained relatively easily by running consecutive replicate analyses. Sampling presents certain physical difficulties which create a great deal of trouble. Nevertheless a proper choice of variables for control experiments to assess this factor can throw considerable light on this source of variability.

Many Control Techniques are Applicable

It has been implied, if not demonstrated, that all common quality control techniques are applicable to chemical production and experimentation. Some of the basic methods have been in use for a long time. Frequency distributions, correlation and tests of significance have been found useful, particularly in laboratory experimentation and research. The scientists in this industry have used the statistical tools useful to scientists in every field of endeavor. Production men have used these techniques less frequently.

To production people, the control chart, a relatively new tool, has perhaps most to offer. It is the simplest, most versatile means of capitalizing on statistics right out on the production floor. Unlike most tools, instead of wearing out with use, it grows with use.

In an industry where processes involving many intricately related variables are the rule, some of the more advanced techniques are proving increasingly valuable. Among these are analysis of variance and sequential analysis. Though they undoubtedly will find their greatest use in the research laboratories of the industry, they are, in their simpler forms, beginning to be used by production men.

The plant operator is often interested in deciding on the relative merits of different processes or machines and wants the answer to such questions as the following. Is the variability in the product produced by a batch process greater than that produced by a continuous one? Does a higher temperature or pressure at a certain stage in the reaction give an improved product? How does time of reaction affect yield? These are only a few of the questions which may be answered by the application of the more complicated statistical methods.

The research chemist, in addition to his interest in precision or reproducibility of his experiments, is much concerned with the interrelationships of variables. Physical testing of such materials as rubber, paper, steel, and plastics may be cited as an example of where the determination of one physical property may be sufficient to predict a number of others. The research chemist will wish to know the reliability with which this prediction can be made. The design of experiments is also a fruitful field for the elimination of waste effort. With proper choice of experimental conditions it is possible to minimize the number of runs needed to determine a particular set of facts

Problems Differ Only in Degree

In the chemical industry, the areas needing control and the elements of the control problem are much the same as in other industries. Raw materials must be tested and accepted or rejected. Production processes must be controlled. Finally, the end product must be classified. As may be said truthfully of the application of quality control to any industry, the differences encountered in the chemical industry are important not in kind but in degree.

MIDDLE ATLANTIC REGIONAL CONFERENCE
PRINCETON UNIVERSITY—DECEMBER 14

More than 250 members and guests assembled for the welcoming address by Dean Condit of Princeton's School of Engineering, after which two parallel meetings convened. That devoted to Analysis of Variance heard Professor Frederick Mosteller, Harvard University, present principles and application of analysis of variance in a form which brings this blue ribbon technique of the statistician to the practicing quality control operator in usable form. Dr. Philip Levine, Ortho Research Foundation, presented the application of statistical analysis in blood group and blood type research. Despite the use of an array of technical terms, this proved to be a most enlightening story of medical research. Professor John W. Tukey, Princeton University, followed with further elaboration of variance principles and an application in the textile field.

The other Section, devoted to Process Control, claimed the attention of a majority of those attending the Conference as both principles and applications of chart control were presented by Mr. O. P. Beckwith, Alexander Smith and Sons Carpet Company, Mr. C. D. Ferris, General Electric Company, Messrs. W. L. Gore and Arthur Kalmbacher, E. I. du Pont de Nemours & Company, Mr. Bernard Hecht, International Resistance Company, and Mr. D. H. Schwartz, Q. M. C. Inspection Service.

Dr. E. Vernon Lewis, du Pont Experimental Station, gave the luncheon speech on "Quality Control in Great Britain." Dr. Lewis pointed out that quality control work is more closely identified with statistical work in Great Britain and observed that they have a similar problem to ours in management apathy. Their tendency to return to pre-war operating methods is probably stronger than ours. He guessed that our willingness to venture into new applications of control technique was somewhat in contrast to the British tendency.

The Conference closed with an afternoon session at which Mr. George F. Smith, President of Johnson and Johnson, presented "Management's Viewpoint of Quality Control". The speaker's knowledge of control operation and his wholly practical attitude toward his company's control system marked him as an executive who understands the purpose of quality control and its place in the kit of management tools.

Third Annual Quality Control Clinic

sponsored by
QUALITY CONTROL ENGINEERS OF ROCHESTER
A Section of the
AMERICAN SOCIETY FOR QUALITY CONTROL
affiliated with the
INDUSTRIAL MANAGEMENT COUNCIL OF ROCHESTER

PLACE: Rochester Chamber of Commerce
55 St. Paul Street, Rochester, New York

DATE: February 18, 1947

REGISTRATION: 11:00 A.M. (no fee)

LUNCHEON: 12:15 P.M. (charge, $1.25)
CHAIRMAN: J. A. Tilton, Delco Appliance Division, General Motors
SPEAKER: Lewis B. Swift, President, Taylor Instrument Company; Chairman of Industrial Management Council.
SUBJECT: Management's View of Quality Control

CLINICS: 2:00 P.M. to 5:00 P.M. (detailed program below)

DINNER: 6:15 P.M. (charge, $1.75)
CHAIRMAN: Halsey H. Kent, Camera Works, Eastman Kodak Company
SPEAKER: J. M. Juran, Professor and Chairman, Department of Administrative Engineering, New York University
SUBJECT: The Quality Control Profession

GAGE EXHIBITORS: Listed in column 3.

CLINIC LEADERS, THIRD ANNUAL QUALITY CONTROL CLINIC

CLINIC 1
Sub-dividing Dimensions for Quality Control Purposes—
C. W. Kennedy
Quality Control Engineer
Federal Products Corp.
Providence, R. I.

CLINIC 2
Selection of Personnel for the Quality Control Organization—
Warren Purcell
Manager Q. C. Dept.
Lamp Division
Sylvania Products, Inc.
Salem, Mass.

CLINIC 3
Sequential Analysis for Measurements—
Irving W. Burr
Department of Mathematics
Purdue University

CLINIC 4
Cooperation between Production and Inspection Department for Success—
C. J. Hudson
c/o Norton Company
Worcester, Mass.

CLINIC 5
Analysis of Variance in the Chemical Laboratory—
Ronald Noel
Bristol Laboratories
Syracuse, N. Y.

CLINIC 6
Product and Process Control in the Chemical Industry—
Professor M. D. Gross
University of Akron
Akron, Ohio

CLINIC 7
How to Interest Management in Quality Control—
E. L. Fay, Chief Insp.
c/o John Deere Tractor Co.
Waterloo, Iowa

CLINIC 8
The Building of a Quality Control Organization—
Paul A. Robert
Quality Control Engineer
I.B.M. Plant
Endicott, N. Y.

CLINIC 9
Practical Use of Histograms in Analyzing Process Quality—
M. D. Benedict
Gillette Safety Razor Co.
Boston, Mass.

CLINIC 10
Sampling Procedures for Products Acceptance—
Arthur Wilder
General Electric Co.
Providence, R. I.

CLINIC 11
Demonstration Construction and Applications of Average and Range Charts—
Professor C. C. Craig
Professor of Mathematics
University of Michigan
Ann Arbor, Mich.

CLINIC 12
Is your Inspection Department Inspecting—
Edwin A. Boyan
Asst. Prof. of Business Management, M.I.T.

GAGE EXHIBITORS

Following is the list of companies that will exhibit equipment at the Clinic:

Pratt & Whitney
Bausch & Lomb Optical Company
R. C. Neal Company, Inc.
Johnson Gage Company
Brush Development Company
Dow Mechanical Corporation
Engineers Specialties Division, The Universal Engraving & Colorplate Company, Inc.
Eastman Kodak Company
The Sheffield Corporation
Size Control Company
B. C. Ames Company
Bryant Chucking Grinder Company
DoAll Rochester Company, Inc.
The VanKeuren Company
Brown & Sharpe Manufacturing Company
Greenfield Tap & Die Corporation
Federal Products Corporation

INFORMATION

Any further questions pertaining to this Clinic should be addressed to Mr. Raymond E. Golemb, Stromberg-Carlson Company, 100 Carlson Road, Rochester 10, New York.

An Aid to Revision of Quality Control Chart Limits*

H. H. FAIRFIELD

FOUNDRY CONSULTANT WITH THE H. W. DIETERT CO., FORMERLY

RESEARCH METALLURGIST, BUREAU OF MINES, OTTAWA, CANADA.

The question most frequently asked by the user of Q. C. Charts is, "How can I tell when to revise the limits?". There are, of course, many practical considerations which tend to divide a process into definite periods. Batches of raw material, new dies, new machine setups, changes of operators, and many other plant conditions should be observed by the Quality Control engineer. The Quality Control Chart should be revised at the time of each major change in the production process.

Intelligent interpretation of the Quality Control Chart requires that the observer be acquainted with the many details of day-to-day operation. The best way to decide when to revise Quality Control Chart limits is to have sufficient experience and judgment of current conditions to know when a definite break in operation occurs.

It frequently happens that average lines from previous data are extended, and current data do not seem to center around the previous average. The engineer requires a method of estimating the probability that the average requires revision.

If it is assumed that the probability that a test value will be greater than the previous average is 0.5, then the probabilities for n values are

$$(\tfrac{1}{2} + \tfrac{1}{2})^n$$

Suppose that six successive observations are made, the

probability that 0 observations will be above average is 1/64
probability that 1 observations will be above average is 6/64
probability that 2 observations will be above average is 15/64
probability that 3 observations will be above average is 20/64
probability that 4 observations will be above average is 15/64
probability that 5 observations will be above average is 6/64
probability that 6 observations will be above average is 1/64

Figure 1 gives a chart by means of which the data can be examined to see if it conforms to the p = .50 binomial. To use the chart, it is merely necessary to count the number of observations above and below the average line, and note the total number of observations and the difference between the number above and below the average line.

For example: 20 consecutive observations are recorded. When compared to the average for previous data, it is found that 17 of these observations are greater than the previous average and 3 of the observations are less than the previous average. What is the probability that the average line requires revision?

Number above—number below = 14

Total number of observations = 20

Probability lies between .02 and .05

More correctly stated: If the previous average is representative then the probability of the occurrence as a chance event of 17 observations above average and 3 observations below average in a series of 20 consecutive observations lies between .02 and .05.

Likewise, suppose that in 20 consecutive observations 16 are found to be below a previously representative average. This case would be recorded as follows:

Number below—number above = 12

Total number of observations = 20

Probability exceeds .10

As is ordinarily the case, statistical analysis provides the basic information. What action, if any, should be taken depends upon the surrounding manufacturing and engineering circumstances. In the first example a series of points have taken a pattern which would be expected only once in about 40 such examples purely as a chance occurrence. This low ratio suggests that it would be in order to investigate the likelihood that this is not a chance event. That is, it would be in order to study this process just as would be done, if one or more points had fallen outside the upper control limit. If an upward shift in the level of the process has occurred, points will fall outside the previously determined upper control limit sooner or later. But the device described here may permit the detection of an assignable cause before the out of control condition has had a chance to develop. The seriousness of the latter situation depends, of course, upon the relation of the control limit to the specified tolerance. If a safety factor is present, the action called for in this example presumably will be a recomputation of the control chart average and limits. If no safety factor exists, corrective action is needed to return the average to its former level.

*Published by the Permission of the Director, Mines and Geology Branch, Department of Mines and Resources, Ottawa, Canada.

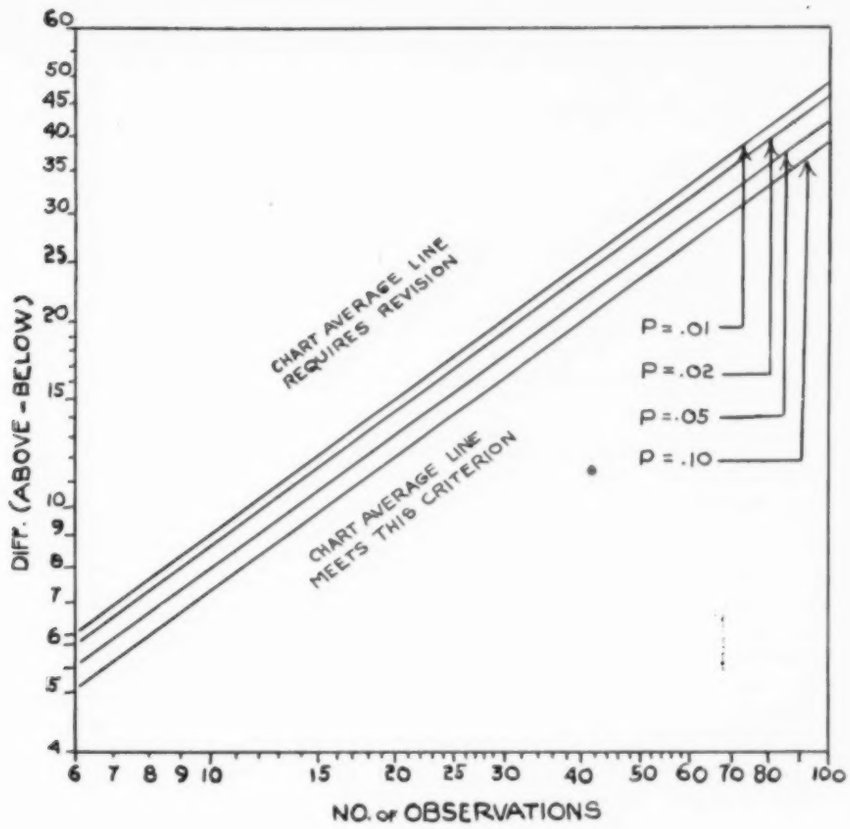


FIGURE 1

An analysis of the statistical evidence may lead to a different line of action in the second example. In this case 16 of 20 points fell below the average, a pattern which might be expected once in ten times purely as a chance event. The question of whether to look for trouble rests on the likelihood of making either of two kinds of error: (1) the error of looking for an assignable cause when none exists; (2) the error of failing to look for an assignable cause which does exist. An event with probability, .10, is not so unlikely that the quality control operator can afford to risk making the first error. He usually can better afford to risk making the second error by waiting for additional evidence. Even this statement must be interpreted in terms of a given set of circumstances. If the control chart under study were a record of the final operation of a long sequence performed on an expensive piece part and undersize pieces had to be scrapped, then clearly it would be safer to risk the first error by investigating this case.

The foregoing should be sufficient evidence of the importance of the earlier statement that statistical analysis provides pertinent information; the proper action depends upon manufacturing and engineering circumstances. Even so, there are certain principles of action connected with the four diagonal lines on the chart. These are merely a summary of the course of action usually followed by quality control operators:

(1) If the point falls below the .10 line, take no action, but follow the case closely.

(2) If the point falls between the .10 line and the .05 line, the case is suspect, do or do not take action according to non-statistical elements of the case.

(3) If the point falls between the .05 line and the .02 line, assume the presence of an assignable cause and act accordingly.

(4) If the point falls above the .02 line, an assignable cause is not only assumed present but is assumed to be an imminent trouble maker; thus calling for immediate corrective action.

All of the preceding has been applied to the chart for averages. The entire argument applies with equal validity to the chart for ranges. In fact, the use of this technique in analyzing the range chart is in some respects more important than its use with the chart for averages, because an increase in the average range means a change in the natural tolerance of the process, a condition which may be much more difficult to correct and one which in the long run will produce more out of dimension product.

The plan developed here is applicable to measurement charts in any quality control installation. The author has found the plan quite useful in operating a battery of from 10 to 30 charts in a steel foundry.

Slide Disk Calculator

G. S. MERRILL

ENGINEERING DIVISION, LAMP DEPARTMENT

GENERAL ELECTRIC COMPANY

Reprint from the **General Electric Review,**

June, 1946, Vol. 40, No. 6, pages 30-33

Review by Doris Newman,

Instructor in Statistics, University of Buffalo

In statistical quality control, the measure of dispersion most frequently employed is the range. Although the efficiency of the range as a measure of dispersion drops rapidly as the number of items in a set of values increases, the ease of computation is in no small way responsible for its popularity. The standard, or root-mean-square deviation, is generally regarded as the most efficient measure of dispersion. It has not been widely used because the calculation involved is somewhat lengthy. The slide disk calculator devised by G. S. Merrill is particularly adapted to the statistical computation of the standard deviation for sets of data for which the number of items is not very large — preferably less than 25. The calculator consists of a disk with a center pin projecting a short distance from the back and sliding in a slot located under the disk. The upper side of the disk is covered with a material such as a heavy drawing paper, into which the point of a pin can be pressed. Mounted at right angles to the slot is an arithmetic movable scale under which the disk may turn and slide, moving the inserted pin horizontally along the arithmetic scale and varying its position vertically with respect to the arithmetic scale. The mathematical principle by which the instrument operates can be briefly illustrated as follows :

Given a set of N values, X_1, X_2, . . . X_n having an arithmetic mean $\overline{X}$, for which the standard deviation is required. Let $x_1 = X_1 - \overline{X}$, $x_2 = X_2 - \overline{X}$, etc. The standard deviation of the set is defined as

$$\sqrt{x_1^2 + x_2^2 + \cdots x_n^2} / N$$

To obtain the value of this expression on the slide disk calculator, successive right triangles are formed; on the first triangle, the sides are the deviations from the means, x_1 and x_2, and the length of the hypotenuse is

$$\sqrt{x_1^2 + x_2^2}$$

This length then becomes a side of the next triangle and the length of x_3 is laid off to form the other side, so that the length of the hypotenuse of the second triangle is

$$\sqrt{x_1^2 + x_2^2 + x_3^2}$$

and so on. The final length desired is then measured in terms of the scale units and with the aid of an alignment chart, this value can be divided by $\sqrt{n}$, yielding the standard deviation.

The slide disk calculator can also be used to determine correlation coefficients by finding the standard deviations of the two lots and the standard deviation of the differences or sums of corresponding pairs of values. No multiplying of corresponding values is required. A curved scale can be added for use in calculating the arithmetic mean of a set of readings and also for calculating the mean deviation from either the arithmetic mean or the median value. The slide disk calculator also simplifies the calculation of the geometric mean based on the logarithms of the values in a set and the standard deviation of the logarithms from their average, and the means and deviations based on any function. In routine calculations, arithmetic scales specially marked for the usual range of values can be prepared. The accuracy of computations can be controlled, and is limited, by this adaptation of special scales to the individual problem.

Training and Refresher Course Provided by the Chicago Section

The Chicago Section of the American Society for Quality Control is at present engaged in an educational enterprise which deserves to be brought to the attention of all members of the Society. Beginning in September 1946 and continuing monthly until June 1947, the Section is presenting a series of instruction classes which are available to all who desire to participate. These classes have regularly drawn an attendance of more than 150 persons, most of whom are not now members of the Section, and the great majority of whom are learning about quality control technique for the first time. They are employees of several score concerns in the Chicago area, and even college students.

The lectures are given without charge by members of the Chicago Section. In earlier lectures the fundamentals of the subject were covered as follows: the concept of control by the use of statistical methods, computation of averages and dispersion, the preparation of a frequency distribution of measurements and the pattern of operating variability, the control charts for measurements, the form of distribution of fraction defective records and the use and interpretation of fraction defective charts, and the parallel development for number of defects. Each lecture has been copiously illustrated by examples drawn from the lecturer's experience. Members of the Section make a point of attending these lectures so that a number of experienced operators will be available to answer individual questions after the formal session has disbanded.

In subsequent lectures more advanced techniques will be presented as follows: analysis of variance, significance tests, correlation, application of probability principles in sampling inspection, and sequential sampling methods. The dates and subjects of these lectures can be found in the July, 1946 issue of INDUSTRIAL QUALITY CONTROL, p. 28.

The Chicago Section put this plan into operation in response to many requests made during the previous year. That the course has succeeded is best attested by the number and enthusiasm of those attending.

LOCAL SOCIETY REPORTS

Southern Connecticut Society for Quality Control

The Second Meeting of the Society was held in the Burroughs Library in Bridgeport on Wednesday evening, 20 November, 1946. Over a hundred members and guests were present.

Chairman Folsom of the Society called the meeting to order and outlined the progress so far made in the organization work of the Society. Mr. Folsom then introduced Mr. C. D. Ferris, Secretary of the Society, who gave a short synopsis of the New England Regional Quality Control Conference in Boston at which he had represented the Society the previous week.

Mr. Folsom then introduced Mr. G. D. Edwards, President of the American Society for Quality Control, as the speaker of the evening. Mr. Edwards had chosen as his subject: "Quality Control And What Our Societies Can Contribute To Its Advancement." His remarks were enthusiastically received by all present, and were followed by a general question and discussion period.

The Delaware Quality Control Society

Dr. Andrew I. Peterson, Quality Control Manager of the RCA-Victor Division of RCA and Vice-president of ASQC addressed a joint November meeting of the Delaware Quality Control Society and the local chapter of the Society for the Advancement of Management.

Mr. Peterson's talk was entitled "The Value of Quality Control to Management" and was divided into two distinct parts, one concerned with the philosophy of the application of Quality Control programs, the other with examples of the value of such program to management.

In the first part of his talk Mr. Peterson stressed the fact that the successful quality control program is the result of the careful integration of a number of factors, one of the most important of which is voluntary co-operation of the several groups of human beings involved in such a program. He stated that the only available economic technique of process control, or of product inspection, is that based on statistical methods, and further, that he believes the present emphasis on statistical quality control is the inception of one of the most economic movements in the history of the science of management.

In the second part of his talk Mr. Peterson cited a number of examples of reduction of scrap and improvement of quality resulting from the use of quality control methods in the manufacture of vacuum tubes.

California Section American Society for Quality Control

The Section met at Hotel Clark at Los Angeles on October 24 for its annual business meeting. The Constitution was amended to bring our fiscal year in agreement with that of the National Society, and to change the name of the Society and officers as recommended by the National Board of Directors. New officers were chosen for the interim period as follows: J. M. Howell, Chairman; Stuart Manly, Vice Chairman; W. H. Lewis, Secretary; Robert L. Turner, Treasurer.

A very interesting talk was given by Stuart Manly, Quality Control Engineer, for the Grayson Heat Control, on the "Psychological Aspects of Quality Control". Mr. Manly emphasized that the Quality Control Section should be a service department. It must give something to the foreman rather than ask something of the foreman. One interesting aspect of the Grayson plant is incentive payment for foremen, which includes control of scrap and rework.

At the December 3 meeting, Mr. J. E. O'Hagan, Vice President and Factory Manager of Grayson Heat Control presented an interesting talk entitled, "Selling the Boss". Mr. O'Hagan pointed out that the regular rules of salesmanship are important in selling quality control. He pointed out four fundamental steps:

1. Know your product Quality Control).
2. Establish confidence.
3. Condition the prospect.
4. Await the proper opportunity to close the deal.

Mr. O'Hagan also emphasized the importance of servicing the account once it is established.

Mr. C. M. Boswell, newly appointed Chairman of the Publicity and Public Relations Committee, presented a plan of action for giving quality control a wider publicity in the California area. Talks before manager groups and magazine articles will serve as a basis for the program.

Hartford Society for Measurement and Control

Although the Hartford Society is one of the newer members of the American Society family, it is a well established going concern with a previous record of many years as a measurements society. Programs thus far this year have brought to our members and guests the following speakers: October 16, Mr. Adam Gabriel, Acme Industrial Co., "Light Waves and Their Use in Industry." November 20, Mr. J. M. Brown, Westinghouse Electric Corp., "Practical Applications of Quality Control Methods." December 18, Mr. F. G. Tatnall, Baldwin Locomotive Works, "Strain Gages and Their Use in Industry." January 15, Mr. F. R. Bokorney, Gisholt Machine Co., "Recent Developments in Balancing Machines."

The speaker at the February 19 meeting will be Mr. Andrew I. Peterson, Manager of Quality Control, Radio Corporation of America, and Vice-President of the American Society for Quality Control. Mr. Peterson's topic will be "Quality Control Applications" and the emphasis will fall on the types of control used in the manufacture of electronic tubes and related equipment.

The officers of the Society are: Chairman, William H. Gourlie; Vice-Chairman, Joseph J. Ferri; Treasurer, Arnold Collins; Secretary, Archie McDougall. The Hartford members of American Society Committees are: Board of Directors, Stanley Johnson; Constitution and By-Laws, Raymond K. Hellman; Membership, Dean Ayer; Publicity, G. L. Manke; Program,

Joseph J. Ferri; Entertainment, Carl Moeller; Attendance, Robert MacGregor.

At the Annual Meeting, May 21, the year's activities will be brought to a close with a combined technical and business session. The speaker for this meeting will be announced later, but all members and their guests are urged to plan ahead to attend this important meeting.

Society for Statistical Quality Control-Metropolitan New York Section

The December 13 meeting of the Society was held jointly with the Conference on Acceptance Sampling of Newark College of Engineering.. The speaker was Professor S. S. Wilks, Princeton University. His presentation of "Future Development in Research and Training for Industrial Statistics" was well received by more than 100 members and guests. This blueprint for future development of quality control is promised in print at a future date by the Newark College. Dr. Walter Shewhart, Bell Telephone Laboratories, commented in masterly fashion on Dr. Wilks' paper. His elaboration of Dr. Wilks' points aided the audience in fixing them clearly in mind.

Pittsburgh Section American Society for Quality Control

At the October 24th meeting at Carnegie Tech., Mr. E. L. Robinson of Carnegie Illinois talked on the "Status of Statistical Methods as Applied to Steel Mill Research". His interesting and practical talk dealt with experience in steel plants.

His remarks can be summarized to some extent as follows:

Control charts are very slowly being accepted by plant personnel. Their opposition is due to lack of education and resistance to the work of keeping the charts.

Mr. Robinson advised the use of simple methods in the plant. He described a simple method of estimating the region within a complex system of variables which gives best results, and stated that it had been quite useful in several instances.

He said the variability in results from one time period to another when using multiple correlation and analysis of variance made it necessary to be very careful in the interpretation of results to management.

Mr. Robinson felt that there is a definite need for education in and use of statistical methods in the plants. He is, however, distinctly concerned about the difficulties involved in gaining their acceptance by both the operating departments and management. For this reason statistical methods may largely remain a tool for specialists.

Society for Quality Control Northeastern Indiana

The November 13 meeting of the Society was held at the International Harvester Company's plant. Mr. Walter Oliver, Timken Detroit Axle Company, presented results of the application of statistical technique to control of sizes of broached holes and how specifications have been rewritten to incorporate knowledge gained from use of control charts. Mr. Frederick J. Halton, Deere and Company, in telling the story of the introduction of quality control methods in plants of his company, stressed the point of view of management that here is a tool not merely for production control, but broadly speaking for finger-tip contact of management with all phases of operations.

Mr. J. E. Rahn, Farmall Works, International Harvester Company, Rockford, was the speaker at the December 11 meeting. His presentation of the methods used in introducing quality control in his plant was instructive to all who attended.

Society for Quality Control State University of Iowa Group

The fall meeting was held at Iowa City, December 13-14. At the morning session of December 13, Mr. R. H. Colvin, Burd Piston Ring Company, Rockford, spoke on "Quality Control vs Piston Rings". Professor Lloyd Knowler presented a technical problem at the afternoon session, after which a business session, dinner, and reconvened business session followed in order. At the concluding session on December 14, Mr. G. G. Parkin, Minnesota Mining and Manufacturing Company, St. Paul, spoke on "Statistical Quality Control Concepts Applied to Waste and Personnel Efficiency" and Dr. Allen T. Craig, University of Iowa, presented a technical problem.

Ohio Quality Control Society

At the Society's November 8 meeting, Mr. W. T. Rogers, National Tube Company, Lorain, spoke on "Quality Control in a Large Steel Mill". Most persons are aware of the complications connected with the application of control technique to the manufacture of steel products. Mr. Rogers' account of how charts and related devices are being used by his company was very instructive to members in other industries as well as to steel men.

Many of the members of the Society attended a Sigma Xi meeting at Case School of Applied Science on November 15 at which Dr. Irving Burr, Purdue University, presented "Statistical Methods in Engineering and Industry".

On December 13 at the regular monthly meeting of the Society, Mr. J. R. Steen, Sylvania Electric Products, Emporium, Pennsylvania, spoke on "Quality Control, the Why and Wherefore" and "Practical Applications of Process Control". Mr. Steen pesented the point of view of his company in developing the use of statistical control in its plants. He also showed the type of control work being done in the Tube Plant at Emporium and reported results of transfer of control information between plants.

Buffalo Section American Society for Quality Control

The November 26 meeting of the Society was held in the Public Library at Lockport and was sponsored by Harrison Radiator Division, Lockport. Mr. Howard Bolton, Harrison Radiator, Buffalo Plant, told the story of beginning production in a new plant with quality control to guide operations. Exhibits of automobile heaters and defrosters aided in showing the problems of assembly control encountered.

Mr. Wilbur Burns, Harrison Radiator, Lockport Plant, presented most vividly by charts and exhibits the use of statistical control in improving the quality of automobile radiator production. The key to his report was the statement that leaks per radiator at initial test had

been reduced from 6+ to 1+ in the space of less than one year through introduction of control charts on the production line. This application carries additional interest because it is control in the presence of skewed distributions. Specifically, the better the workmanship, the more skewed the distribution of leaks.

Chicago Society for Quality Control

At the Chicago Society's November meeting Professor I. W. Burr of the Department of Mathematics, Purdue University, presented the results of his research on the application of sequential analysis of measurements to the setting or resetting of a manufacturing process. This paper, which was very well received, contained information for which many of the members had immediate practical application.

Through the use of constants for a chosen degree of sampling risk Professor Burr developed a set of economical acceptance and rejection limits for determining whether a given process is set at the desired level and for determining when resetting is required. The constants are so set up that the sequential sampling either gives assurance that the process is set for satisfactory operation or indicates the need for resetting when the level of quality drifts a chosen distance in either direction from the desired mean. These decisions are arrived at with a minimum of sampling effort which is performed in a sequential manner.

Announcement was made at the November meeting that the Society's twenty-five dollar award for the best original paper on Quality Control by one of its members during the 1945-46 period had been won by Mr. H. L. Jones of the Illinois Bell Telephone Company. Mr. Jones' paper, on "Sampling Plans for Verifying Clerical Work", appears in this issue of **Industrial Quality Control.**

Quality Control Engineers of Rochester

The December dinner and meeting attended by 160 members and guests was held at the Rochester Chamber of Commerce on Tuesday, December 17.

John Centa, E. I. DuPont, Defender Division, newly appointed director to replace R. K. Dean, formerly of Defender and now residing in Vermont, was introduced to the members by President Halsey Kent.

The gage control sub-group meeting with Chairman W. L. Myers, Gleason Works, has been working with A. L. Davis of the Rochester Institute of Technology staff to plan a program in the field of precision measuring. The course, called **Precision Measurement,** is reported to be completed and will be offered in the school term beginning January 13th.

Warren Purcell, Manager Quality Control Department, Lamp Division, Sylvania Products Inc., presented an interesting talk on **Quality Control at Work.** Stating the need in his company for a Quality Control Technician to coordinate and direct the work of on the job control engineers, he outlined to the group ten qualifications necessary for the man in this position if he is to use effectively the modern techniques of Quality Control.

The first Quality Control Meeting of the Rochester Chapter for 1947, was held Tuesday, January 21, at the Chamber of Commerce.

It was a panel discussion on "Quality Control At Graflex, Inc.", Rochester, New York. The speakers on the panel, all members of the Graflex organization, were as follows:

M. B. Moore, Assistant Chief Engineer, "What Management expects of Quality Control."

David Ohl, Quality Control Engineer, "Quality Control—A service to Engineering and Production."

P. G. Fishback, Quality Control Staff, "Gage Control and Measurement Techniques at Graflex."

Each subject was handled very well by the individual speakers, resulting in a very lively question and answer period.

We had 175 present and this meeting stands as being one of the best, so far, of the 1946-47 Season.

AMERICAN SOCIETY NEWS

Founding Memberships

The National Officers are receiving an increasing number of inquiries from members and prospective members in all parts of the country with respect to Founding Memberships in The American Society for Quality Control. The following information may serve to answer similar questions in the minds of others who may not yet have had occasion to initiate specific inquiries.

The American Society Constitution provides that any member of the Society "may become a Founding Member by paying an additional sum of not less than five dollars before June 30, 1947."

Up to this time, 148 members have exercised their privilege of becoming Founding Members. The first Year-Book of the American Society for Quality Control will list the names of these and subsequently enrolled Founding Members as a part of the permanent records of the Society.

The opportunity is hence still open to all present members to take up Founding Membership prior to June 30, 1947, by sending an additional sum of not less than five dollars to Mr. Ralph E. Wareham, Executive Secretary, 305 East 43rd St., New York 17, N. Y. Similarly prospective members may join the Society directly as Founding Members by sending not less than $7.50 to the Executive Secretary, but this privilege will cease at June 30, 1947.

Convention News

The November issue of INDUSTRIAL QUALITY CONTROL carried an advance notice of the First Annual Convention of the American Society for Quality Control, to be held at the Sherman Hotel in Chicago on 5th and 6th June, 1947.

The working out of plans for the Convention is continuing and these will be announced in subsequent issues of INDUSTRIAL QUALITY CONTROL as rapidly as they are completed.

The Exhibits Committee has completed a brochure showing the diagrams, locations, rental prices, etc., for the sixty exhibit spaces which will be available for the Convention, together with the rules and other arrangements governing exhibits. A number of the spaces have already been sold. Desirable spaces are still available, but it is suggested that early choice and reservation be made. Copies of the exhibit space brochure may be obtained by addressing:

Mr. Henry J. Becker, Exhibits Chairman
c/o American Steel and Wire Co., Waukegan, Illinois

Members are again urged to make their reservations for the Convention as early as possible. It is apparent that the full accommodations for the main dinner and at least one of the luncheons will be sold out long in advance of the meeting. This will also probably be true for some of the clinics, as well as for hotel rooms. Reservations should hence be sent as soon as possible to:

Mr. Harold R. Kellogg, General Secretary
P.O. Box No. 1097
Chicago 90, Illinois

This Convention offers the first opportunity for a general meeting of the membership of the American Society for Quality Control. A general report will be made to the Convention on the progress which has been accomplished so far in the organization of the Society, on its aims, and on the direction in which it appears to be moving. The Convention offers real opportunity for the members to discuss these matters, to become better acquainted with each other, to exchange ideas, to acquire information and inspiration which will be of real value in their work, and finally to have an all around good time. It is hoped that it will attract attendance of a wide representation of the membership from all of the local Sections throughout the United States and Canada, as well as of the members-at-large.

American Society News
Additional Local Societies Affiliated

Three additional local Societies have recently become Sections of the American Society for Quality Control, viz:

Southern Connecticut Society for Quality Control.

Southern Tier Society for Quality Control.

Toronto Quality Control Society.

With these additions, the American Society now has twenty-five active Sections.

Terms Fixed For Members of Board of Directors

The Constitution and By Laws of the American Society provide that the terms of one-half of the Directors shall expire on 30 June, 1947, and the balance one year later. Thereafter, the terms of all Directors are to be for two full years. The Board is directed to determine the length of the initial terms of the several Directors and the Board has now made this determination.

Including a number of recent changes and additions to the Board of Directors, its composition is now as follows:

OFFICERS — Terms expiring 30 June, **1947**

President:
George D. Edwards

Vice President:
Andrew I. Peterson

Executive Secretary:
Ralph E. Wareham

Treasurer:
Alfred L. Davis

Chairman, Editorial Board:
Martin A. Brumbaugh

DIRECTORS — Terms Expiring 30 June, **1947**

Boston:
Charles J. Hudson

California:
John M. Howell

Delaware:
Arthur R. Kalmbacher

Hartford:
S. G. Johnson

Indiana:
Harry B. Marsh

Michigan:
Herbert G. Winter

Newark:
Paul S. Olmstead

Ohio:
Wade R. Weaver

Philadelphia:
Harry W. Poole

Rochester:
Halsey H. Kent

Southern Connecticut:
Charles D. Ferris

Syracuse:
Richard W. Coolbaugh

Western Massachusetts:
Morton M. Newcomb

DIRECTORS — Terms expiring 30 June, **1948**

Buffalo:
Alfred J. Winterhalter

Chicago:
Ernest H. Robinson

Georgia:
Ralph A. Hefner

Illinois:
Roman M. Hammes

Iowa:
Frederick J. Halton, Jr.

Milwaukee:
Bernard F. Litzau

North Eastern Indiana:
K. E. Ross

Omaha:
Carl W. Helmstadter

Pittsburgh:
Earl W. Mahaney

St. Louis:
L. S. Kauffman

Southern Tier:
Merlin J. Barret

Toronto
B. A. Griffith

Terms of Executive Committee Members

As a result of determination by the Board of Directors of the terms of the several members of the Board, the terms of the present members of the Executive Committee of the American Society have been automatically fixed as follows:

OFFICERS — Terms expiring 30 June, **1947**

President:
George D. Edwards

Vice Pesident:
Andrew I. Peterson

Executive Secretary:
Ralph E. Wareham

Treasurer:
Alfred L. Davis

Chairman, Editorial Board:
Martin A. Brumbaugh

REGIONAL DIRECTORS—Terms expiring 30 June, **1947**

New England:
Charles J. Hudson

Middle Atlantic:
Paul S. Olmstead

Central:
Wade R. Weaver

Western:
John M. Howell

REGIONAL DIRECTORS—Terms expiring 30 June, **1948**

Northern:
Alfred J. Winterhalter

Mid-West:
Frederick J. Halton, Jr.

Executive Committee Meeting Buffalo, 28 September, 1946

In addition to those items reported on in the November Issue of INDUSTRIAL QUALITY CONTROL, the following matters were considered at the September meeting of the Executive Committee of the American Society for Quality Control:

General Committees

The President reported activation of all of the General Committees authorized by the Executive Committee, as follows:

Committee on Membership
Committee on Relations with Educational Institutions
Committee on Programs and Speakers
Committee on Publicity and Public Relations
Committee on Relations with other Technical Societies

Committee on Professional Ethics and Qualifications

As its Chairman, Mr. Hudson reported that the Committee was hard at work on the problem of personal consultant advertising in INDUSTRIAL QUALITY CONTROL, which had been referred to the Committee by the Executive Committee for recommendations. It was Mr. Hudson's feeling that solution of this problem would probably require establishment of grades of membership in the Society, with suitable qualification requirements for each grade. He indicated that the Committee was giving careful consideration to this proposal.

Technical Committees

The President suggested that the Society would probably ultimately wish to have Technical Committees, each responsible for activities in connection with the development of one major phase of quality control and for encouraging technical meetings and the presentation of technical papers in connection therewith.

Real need had already appeared for such a Committee which would be responsible for standardization of definitions of quality control terms, nomenclature, and symbols. The Executive Committee authorized the President to appoint a Committee on Standardization which could undertake these responsibilities.

Translation of Members

The Executive Secretary reported receipt of requests from a number of individual members that they be transferred from one local society Section to another Section. He requested instructions as to the handling of such requests.

The Executive Committee agreed that any member may be translated from one Section to another at any time at his own request, but that the corresponding credit or transfer of local dues was a matter for determination by the Sections involved. It was the general feeling of the Executive Committee that since less than one year's dues would ever be involved, such transfer of local dues already paid might well be waived by the Sections.

First Annual Convention

Mr. Halton reported that he was authorized, on behalf of the General Committee of the Second Mid West Quality Control Conference, to extend to the American Society an invitation to make that Conference its First Annual Convention. He stated that the organization and facilities of the Second Mid West Quality Control Conference would be at the disposal of the Society for the Annual Convention, and that the technical and other portions of the program would be arranged to meet the needs of the American Society Convention. Conference and banquet rooms, etc., had already been reserved at the Sherman Hotel in Chicago for Thursday and Friday, 5th and 6th June, 1947, and blocks of sleeping rooms had also been reserved at the Hotel Sherman.

Following discussion of further details involved in the necessary arangements, the Executive Committee decided to accept the invitation of the Second Mid West Quality Control Conference. The President was authorized to make such arrangements and appoint such Committees as necessary for co-operation with the Mid West Conference Committee in the conduct of the Convention.

Executive Committee Meeting New York, 15 December, 1946

The Executive Committee of the American Society for Quality Control held a five-hour meeting at the Harvad Club in New York City on 15 December, 1946. Present were Messrs. George D. Edwards, Chairman; Ralph E. Wareham, Secretary; Andrew I. Peterson, Alfred L. Davis, Martin A. Brumbaugh, Charles J. Hudson, Paul S. Olmstead, Alfred J. Winterhalter, Wade R. Weaver, and Frederick J. Halton, Jr.

The Executive Secretary reported that the membership was almost 1500, and the Treasurer reported a balance on hand slightly in excess of $4000. The Treasurer warned however, that this apparently large balance should not lead the Society into any commitments not absolutely necessary, since necessary expenditures for the magazine, etc., for the bal-

once of the year would practically exhaust it. The Chairman of the Editorial Board submitted a report covering operations of the magazine, and recommended 32-page issues at least for the balance of the current fiscal year. This last-mentioned recommendation was adopted, and all three reports were accepted as pesented.

For the Committees on Professional Ethics and Qualifications and on Constitution and By Laws, their respective Chairmen, Messrs. Hudson and Halton, reported expectation that they would be able to meet a schedule tentatively proposed by the President, under which a new Constitution would be submitted to the entire membership of the Society to be voted on by postal ballot in advance of the Annual Meeting of the Society on 27 June, 1947.

After substantial discussion, the Executive Committee approved an arrangement under which Regular Members joining the Society after 1 January of any year may pay one-half of the annual dues for that fiscal year and will receive INDUSTRIAL QUALITY CONTROL for the complete half-year for which they pay dues. Such members will have the option however, of paying dues for the whole fiscal year and thus receiving the full year's issues of the magazine. This arrangement will in no way affect the Founding Membership privilege, which will terminate on 30 June, 1947, and which requires a payment of at least $5.00 in addition to the dues required for Regular Membership at the time of payment of the latter.

The Executive Committee considered at some length the desirability of publishing a Year Book of the Society, and authorized the President and Executive Secretary to get out such a book as early as possible after 1 January, 1947. The Year Book would include a complete roster of the Officers, Committees and members of the Society, and a copy would be furnished without charge to each member.

Change in Committee On Membership

Mr. T. T. McNelley has been appointed to represent the North Eastern Indiana Section in the Mid West Region on the Committee on Membership, replacing Mr. D. H. Mills, resigned.

Nominating Committee Appointed

The Constitution and By Laws of the American Society require the President to appoint a Nominating Committee from the membership of the Board of Directors, —one Director to be appointed from each of the six Regions. It is the duty of this Committee to nominate one or more candidates for each of the offices of President, Vice President, Executive Secretary, and Treasurer, to serve for the fiscal year beginning 1 July, 1947.

The President has accordingly appointed the following to serve on the Nominating Committee.

New England:
Mr. Morton M. Newcomb
17 Sumner Avenue
Springfield, Massachusetts

Middle Atlantic:
Mr. Arthur R. Kalmbacher
1409 Grant Avenue
Wilmington 49, Delaware

Northern:
Mr. Herbert G. Winter
34,904 Ash
Wayne, Michigan

Central:
Mr. Wade R. Weaver
418-A Republic Building
Cleveland, Ohio

Mid West:
Mr. Ernest H. Robinson
c/o Johnson & Johnson
4949 West 65th Street
Chicago 38, Illinois

Western:
Mr. John M. Howell
4140 West 63rd Street
Los Angeles 43, California

Any member of the above Committee will be glad to receive suggestions from any member or members of the Society with regard to desirable nominees for any office. In this connection, members should have in mind the constitutional provision making the President and Vice President ineligible for reelection to the same office. There is no such prohibition with regard to reelection of the Executive Secretary or the Treasurer.

Publication Date for American Society Year Book 1946-47

The 1946-47 Year Book of the American Society for Quality Control will go to press as of 1 March, 1947.

It will contain, as of that date, a complete roster of Founding Members, a complete roster of corporations and companies which have made founding contributions to the American Society, a complete roster of all Officers, Boards, and Committees of the American Society, a complete roster of the Officers and American Society members of all local society Sections, as well as much other information of interest and reference value to members.

A copy of the Year Book will be furnished to every American Society member without charge, as a privilege of membership.

It is urged that anyone contemplating Founding or Regular membership or making a founding contribution, should act promptly so that the Year Book record will be as accurate and complete as possible. Members contemplating changes in address or company connection should also notify the Executive Secretary as soon as possible so that corresponding changes in the Year Book record can be made.

No changes in the Year Book information can be made after 1 March, 1947.

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(Second edition, 1947)

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Editorial

In recent issues of INDUSTRIAL QUALITY CONTROL an earlier custom of devoting one page to an editorial presentation has been discontinued. In the main the loss from suspension of this function has been minor, and, indeed, there is no present intention of reviving the practice. In this case space has suddenly become available which provides an opportunity to say something directly to readers, that has been in the minds of the Editorial Board for some time.

The flow of prospective articles to the Editors from members has been most gratifying both in number and in content. At the present time a moderate backlog of articles is available and ready for revision or final editing. At the same time a gap is apparent in these articles. There are not enough plain unvarnished stories of applications of control charts and allied control techniques in production and assembly areas. We believe that a mass of such stories is available in your plants. At the same time we recognize that you are busy and that writing is not part of your job. But your fellow members of the American Society need to hear your story. This dilemma was foreseen when the Constitution of the American Society was formulated. Provision was made for the appointing of a local editor in each Section whose function would be to assist members of his Section in the preparation of articles for submission to the Editorial Board. In most of the Sections this local editorial function has been assigned to the Section's member on the American Society Committee on Publicity and Public Relations.

A request is hereby addressed to members to work with their local editors in preparing articles for INDUSTRIAL QUALITY CONTROL. A request is hereby addressed to local editors to assist by encouraging members to prepare articles concerning their work.

On this score a review of editorial policy is in order. The following is quoted from Volume I, No. 1, of INDUSTRIAL QUALITY CONTROL.

"The Constitution of the [Buffalo] Society states that, 'The object of this Society is to collect, analyze, and disseminate information concerning Quality Control as applied to industry.' This Journal has been launched for the purpose of implementing the quoted article of the Constitution . . .

"The quoted article from the Constitution places emphasis on the application of Quality Control. That point of view will be a guiding principle of this publication. Other publications are available for the presentation of statistical and mathematical developments of interest to quality control operators. Likewise the engineering approach is available. But between these two there is an open area of analytical quality control in industrial use. Into this open area INDUSTRIAL QUALITY CONTROL is projected as a service to the men and women who make the decisions from day to day in quality control departments."

In subsequent stages of magazine development there has appeared to be some tendency to diverge from this fundamental purpose. Yet your Editorial Board has never ceased to believe that publication of information of value to the great body of quality control operators who are neither statisticians nor engineers is its major mission.

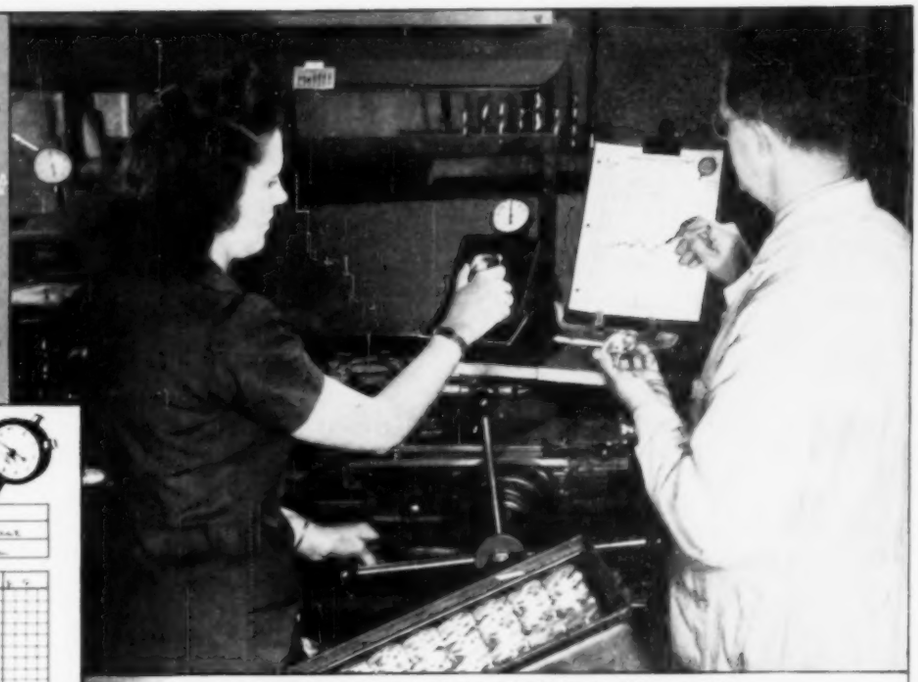
The articles being received currently show plainly that somehow there has developed a belief that a prospective article must contain some new technique. This is definitely not the case. We need straightforward stories of applications from the men who are doing the work.

Broadly speaking there are three types of articles which are needed: (1) stories of applications of established techniques, (2) explanations of how to apply new techniques, (3) new developments usable at the operating level. Balance between these types of articles in each issue of the magazine is the objective of the Editorial Board. This can be accomplished only through the interest and cooperation of members.

The members of the Editorial Board are engaged at present in the codification of a set of policies for the magazine and subsequently will set up some rules for form of manuscripts. This has proved to be a somewhat lengthy enterprise which cannot be completed for sometime. In the meantime authors have without exception been completely cooperative in preparing manuscripts in a form which has reduced the editorial work. Under these conditions the Editorial Board can avoid hasty action and can ultimately produce operating policies that will require little amendment in the future.

The Editorial Board also recognizes that the liaison with the Local Editors referred to above is practically nonexistent. This will be remedied gradually as the Board's organization stabilizes. In the meantime the Local Editors of some Sections are producing manuscripts. The Board appreciates this cooperation and urges the Publicity Committee members of other Sections to search actively for eligible prospective manuscripts.

DIMENSIONAL QUALITY CONTROL



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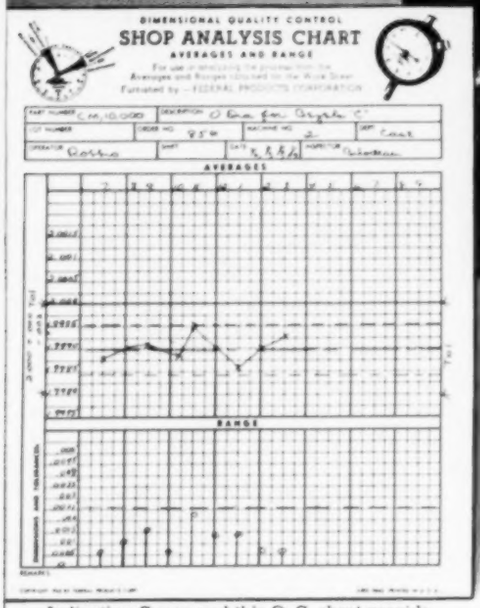

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